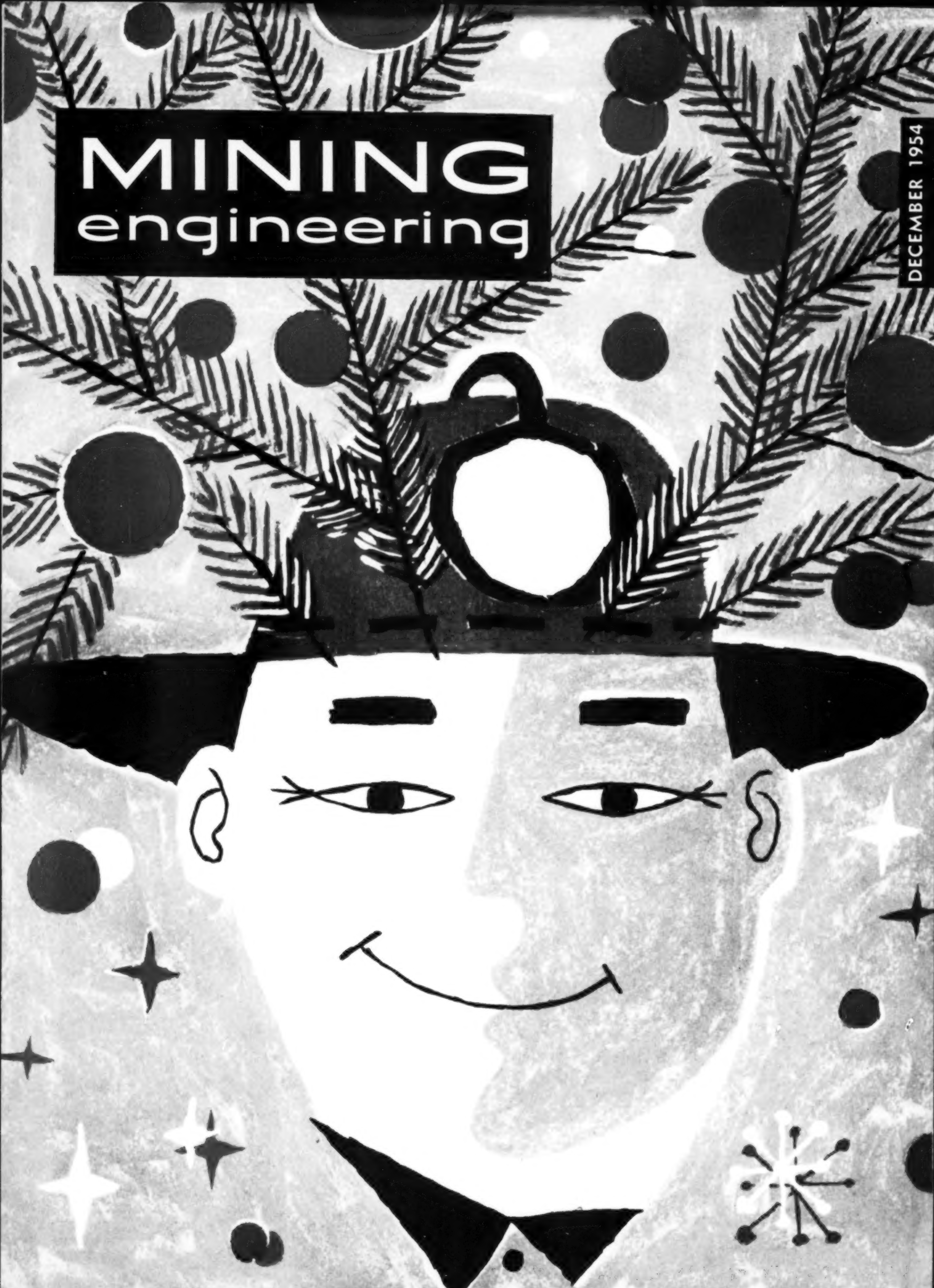
MINING engineering

DECEMBER 1954



MINING engineering

VOL. 6 NO. 12 DECEMBER 1954

The AIME publishes Mining Engineering / Journal of Metals / Journal of Petroleum Technology

Published monthly by the American Institute of Mining and Metallurgical Engineers, Inc., 29 West 39th St., New York 18, N. Y. Telephone: PEnnsylvania 6-9220. Subscription $8 per year for non-AIME members in the U. S., & North, South & Central America; $10 foreign; $6 for AIME members, or $4 additional in combination with a subscription to "Journal of Metals" or "Journal of Petroleum Technology". Single copies $.75; single copies foreign $1.00, special issues $1.50. The AIME is not responsible for any statement made or opinion expressed in its publication. Registered cable address, AIME, New York. Indexed in Engineering Index, Industrial Arts Index, and by The National Research Bureau. Entered as second-class matter Jan. 18, 1949, at the post office at N. Y., N. Y., under the act of March 3, 1879. Additional entry established in Manchester, N. H. Member, ABC

COVER

SEASONS GREETINGS from the Editors of Mining Engineering
Cover by Herb McClure

FEATURES

Personnel Service	1134	Drift	1163
Manufacturers News	1148	AIME News	1213
Books	1144	Personals	1221
Reporter	1153	Professional Services	1226
Mining News	1157	Coming Events	1228
Trends	1160	Advertisers Index	1228

Letters to the Editor 1138

ARTICLES

Mining Methods at the Barberton Limestone Mine — H. F. Haller 1164

The Search for Australia's Uranium — H. J. Ward 1169

Rotary Drilling Fluids in Exploration Drilling — W. D. Lacabanne 1174

Diamond Core vs Churn Drilling in Exploration — Frank J. Anderson 1178

TRANSACTIONS

Operation of FluoSolids Roaster at Golden Cycle — Howard R. Keil 1181

Diamond Drilling Problems at Rhokana — O. B. Bennett 1186

Improvements in Plant and Operations at Pueblo Coal Washery—Colorado Fuel & Iron Corp. — J. D. Price and W. M. Bertholf 1190

Adsorption of Dodecylammonium Acetate on Hematite and Its Flotation Effect — A. M. Gaudin and J. G. Morrow 1196

Magnetic Attraction of Stacked Drill Rods — John L. Baum 1203

Near-Surface Hydrocarbons and Petroleum Accumulation at Depth — Leo Horvitz 1205

Effect of a Variable Surface Layer on Apparent Resistivity Data — Harold M. Mooney 1211

—Personnel Service—

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Chief Engineer, 49, married, graduate electrical engineer. Has been responsible for electrical, mechanical, shops, construction, maintenance and preparation departments of large coal company; 12 years and 13 years sales and application electrical equipment with large electrical manufacturer. Desires executive or administrative engineering position or administrative sales position. Available immediately. Will relocate. M-106.

Mining Geologist, B.A., M.Sc., 38. Desires to return to U. S. with family. Fifteen years broad experience in applied geology includes ore-finding, exploration, evaluation, geochemistry. Wants responsible position with mining company in eastern or western U. S. or will consider work on consulting or fee basis. M-107.

Mining Geologist, 31, married; 7½ years experience with mining companies throughout West. M.S. degree economic geology. All phases of exploration, development, evaluation, and operation. Desires permanent position requiring limited traveling. Available 30 to 60 days; prefers western states. M-108-1012-E-San Francisco.

Registered Mining Engineer, 32, married, graduate. Two years examinations, reports, supervising exploration; 2 years supervising production, research, and engineering projects; 2 years constructing and operating mills, HMS, flotation, magnetic separation, jigs, tables. Desires responsible position with reputable company. Available now. No location preference. M-109-1013-E-San Francisco.

Mining Geologist, service returnee, 25, single, B.S. in geology, Columbia '52, plus 1 year of graduate work in mining engineering. Knowledge of engineering law, accounting, electronics. Engineering background. Work does not necessarily have to be technical. Desires position with future in the northeastern part of the U. S. M-110.

Metallurgist, 29, single. Four years experience mineral dressing and extensive testing in laboratory at large mining company. Desires employment in mineral dressing or extractive testing. Available January 1955; prefers northern California. M-111-1115-E-San Francisco.

MINERAL PREPARATION ENGINEER
Mining Engr., M.S., Ph.D. Experience: 12 years design operation flotation plants, 2 years design estimating coal preparation plants. Speaks English, Spanish, French. Seeks responsible position with American or European company in South America.
Box K-17 AIME
29 West 39th St., New York 18, N. Y.

TEACHING POSITION AVAILABLE

in the Mining and Metallurgical Department to teach ore dressing. Academic rank and salary depend upon experience. To join faculty in September 1955.

Write—Chairman
Texas Western College
of the University of Texas,
El Paso, Texas

—— POSITIONS OPEN ——

Exploration Manager, under 45, preferably with advanced degree in geology, and at least 10 years experience as field geologist. Must have good knowledge of theory and application of geophysics in order to evaluate findings of exploration teams. Permanent. Salary open. Location, West. S-238.

Geologist or Geophysicist, under 45, graduate with experience in economic geological and geophysical exploration work. Permanent. Salary open. Must be willing to travel. Location, West and Southwest. S-143.

Head for Dept. of Mining Engineering, 38 to 50, with at least M.S. in mining engineering and some good experience in the industry. Should also have some teaching experience. Location, Midwest. W188.

Mining or Metallurgical Engineers, graduates, 25 to 40, experienced as mill shift bosses or experienced in metallurgical research work. Favorable climate; modern housing available. Apply by letter stating age, educational background, experience, salary requirements, and when available. Location, West Coast. W618-S.

Safety and Ventilation Engineer, 35 or over, experience in underground metal mining essential, and must be capable of making mine ventilation surveys and promoting mine safety program. Salary, $5500 to $6000 year. Location, Northwest. S193.

Assistant Mine Superintendent, experienced working narrow, irregular veins, cut and fill stoping; supervise development and maintain equipment. Must speak Spanish. Quarters furnished for married man. Salary $6000 to $7000 a year. Elevation 13,500 ft. Location, South America. S-252.

Chief Mine Engineer, with broad experience in metal mining. Will be responsible for all engineering functions in department of 120 men. Three-year contract, first 6 months single status. Good climate and living conditions. Salary open. Location, Philippine Islands. S-200.

Mill Metallurgist Assistant, young, with several years experience in ore separation. Single status. Salary open. Location, Guiana. F593.

Mine Superintendent, preferably with chrome mining experience, to take charge of property operations. Salary open. Location, northern California. S251.

MINING EXECUTIVE

Prominent Midwest coal corporation wishes to strengthen its middle management team with an outstanding mining executive. Preferably under forty; engineering degree. Will be groomed for top echelon responsibilities.

Box K-19 AIME
29 West 39th St., New York 18, N. Y.

GEOLOGIST - ENGINEER

Central New York industrial firm has permanent position with opportunity for man with combination of geology and civil or mining engineering. Must have experience. Submit complete resume and salary requirements in first letter.

Box K-18 AIME
29 West 39th St.
New York 18, N. Y.

MINE SUPERINTENDENT

Exceptional opportunity for very hard-working mining engineer with strong interest in geology, 30 to 40 yr. old, with demonstrated supervisory ability and experience particularly underground mining methods for work at mine operated by chemical company to insure mercury supply. Write fully, including photograph, resume of college records, experience and references to Dr. S. J. Buckman, Buckman Mines, Geyser Road, Cloverdale, Calif.


Increase your footage
Use CLEVELAND Air Legs and Drills...the easiest way
CLEVELAND
CLEVELAND Air Leg
THE FEED YOU NEED — FROM ZERO FEED TO FULL LINE
Eleven detent positions enable drill operator to set and maintain pressures in a range from zero to full-line feeding pressure — with an increase of 9 psi at each setting. That's why a CLEVELAND Air Leg and H10AL Drill combination gives top performance in any kind of rock.
Shown here is a CLEVELAND AL-92 Telescopic Air Leg with H10AL Drill. Because of space limitations, full length isn't shown.
CLEVELAND AL-92 Telescopic Air Leg with H10AL Drill and exclusive 11-position feed control
SPECIFICATIONS
Standard, automatic controlled wet-type backhead.
Chuck Sizes ... 7/8" x 4¼" — or other popular steel shank sizes
Weight, Drill ... 60 lbs.
Air Hose ... ¾"
Water Hose ... ½"
Full Feed Travel ... 4' 6'
Collapsed Feed ... 2' ea. piston 3' ea. piston
Closed Length ... 48" 60"
Extended Length ... 96" 132"
Air Leg Weight ... 37 lbs. 42 lbs.
CLEVELAND AL-90 Single Extension Air Leg for use with H10AL Drill and exclusive 11-position feed control
SPECIFICATIONS
Weight, Drill ... 60 lbs.
Air Hose ... ¾"
Water Hose ... ½"
Feed Travel ... 36" — 48" — 60"
Closed Length ... 56¾" — 69" — 81¼"
Extended Length ... 92¾" — 117" — 141¼"
Air Leg Weight ... 30 lbs. — 34 lbs. — 37 lbs.
CLEVELAND AL-91 Single-Extension Air Leg for use with any 35-lb., 45-lb., or 55-lb. class rock drill. Feed control built into air leg.
SPECIFICATIONS
Standard wet, or automatic controlled, wet-type backhead available.
Air Hose ... ¾"
Water Hose ... ½"
Feed Travel ... 36" — 48" — 60"
Closed Length ... 58" — 71" — 83"
Extended Length ... 94" — 119" — 143"
Air Leg Weight ... 35 lbs. — 38 lbs. — 41 lbs.

Letters to the Editor

Reminiscences

I note Mr. Benedict's comments on the advances in nonferrous metallurgy, or rather ore dressing, in the current number of MINING ENGINEERING, (October 1954, pp. 976-7) 'Pop' Richards was leading the summer school in mining engineering of the MIT class of 1900, in Nova Scotia in the summer of '98 and we were doing the usual thorough job of measuring and sketching such trifles as hastily whittled out paddles of wood as well as the important things in the machinery line when Professor Richards received some very important and disturbing mail.

The next morning he told us that a great improvement had been made in ore dressing by a man named Wilfley who had invented a new table and that it would make useless the 300 pages he had just written for his forthcoming book on ore dressing.

I had had more experience in mining than the rest of my class because I had spent the summer of '96 helping to run a 20-stamp mill on Jim Creek, below Ward, Colo. Part of the equipment were Gilpin bumpers—Mr. Benedict, please note—which seemed to do a fairly satisfactory job on the coarse stuff, but the arsenical-pyrite fines that came down the stream from the mills above nearly laid me out until I filtered the drinking water. Our saddle horses became so fond of this water clouded with slimes from the mills above that they would wait for a drink of it when they knew we were on the way back to camp.

I asked Prof. Richards if the bumpers were not as effective as the Wilfley and his reply was most emphatic, "No, Morris, there is no comparison between the two tables in effectiveness," and I learned later there wasn't.

What induced me to write was Mr. Benedict's statement that "The jig and revolving table were our only mechanical equipment for recovering values, etc., etc." The bumper, as we called it, was in quite common use in Colorado before the turn of the century and, given a crushed product without too much fines, was reasonably efficient.

HENRY C. MORRIS

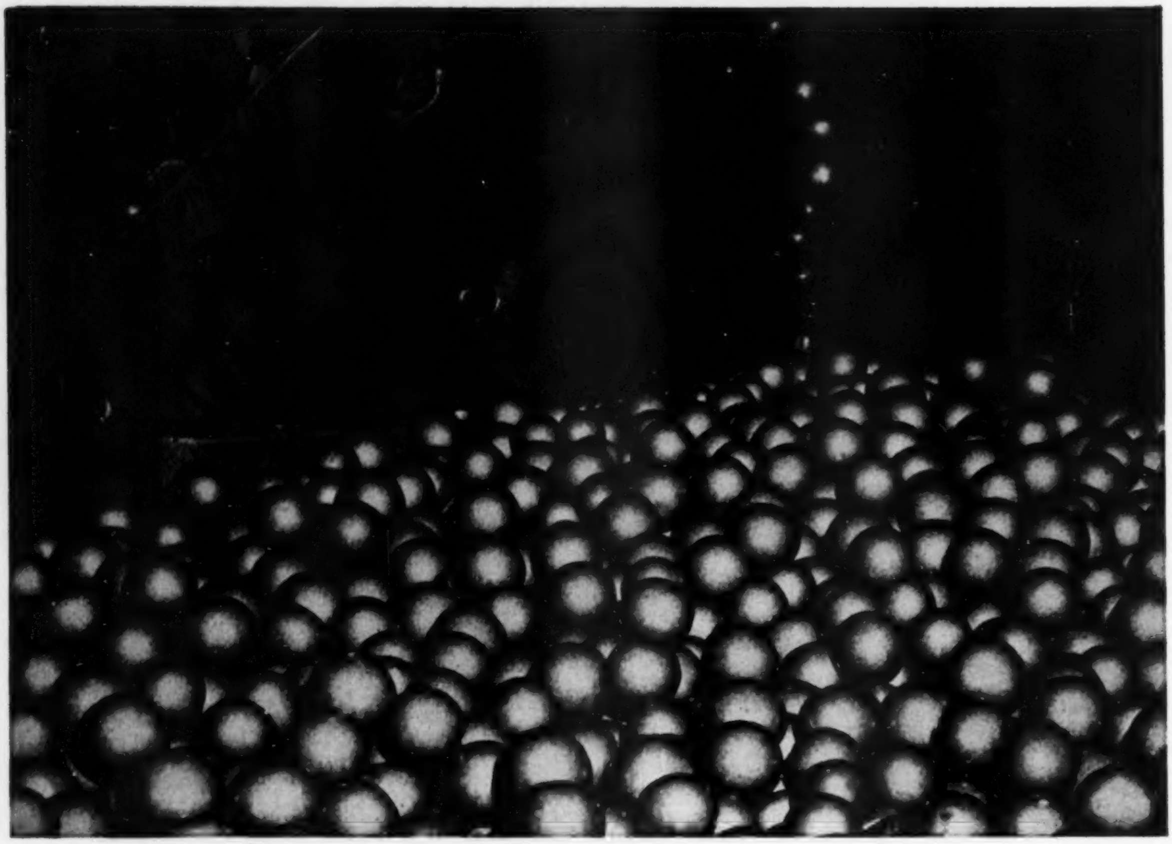
Confusion

In the April 1954 issue, (p. 416) a paper on *Flotation of Oxidized Zinc Ores* by the writer and others was published as TP 3768B. A misprint happened in the abstract on p. 416 and it was stated that the flotation process had treated so far "more than 10,000 tons of ore."

Now this process has been in use since 1950, and the correct figure was "more than 100,000 tons of ore." This of course makes a lot of difference and I was sorry that the readers of the magazine would have the erroneous impression that the process was just in its beginnings, when in fact it has been proved on a mill scale for several years. In the conclusion of the paper, p. 420, the figure of 100,000 tons was correctly given.

M. REY

This is a case of confusion compounded by confusion, on our part. This is the fact in this case: More than 100,000 tons had been treated by the process at the time the article was written. A correction published in the August issue, (p. 808) was itself in error. The correction was wrongly applied to the figure of 100,000 tons given in the conclusion of the article, wrongly reducing this figure to 10,000. We apologize. Mr. Rey was kind to call it a misprint. We repeat: 100,000 tons is the final, correct figure.



Books for Engineers

Please Order the Books on this page from the Publishers

Accident Facts, *National Safety Council*, 425 N. Michigan Ave., Chicago 11, Ill., 75¢, 96 pp., 1954.—Facts and figures on all types of accidents —industrial, traffic, home, farm, and school. Twenty pages are devoted to occupational accidents and provide factual background for an industrial safety program. Charts show the accident trend for past 25 years.

Geologic Quadrangle Maps, by Virgil E. Barnes, No. 15 Wendel Quadrangle, Gillespie, Kerr, and Kimble Counties; No. 16, Harper Quadrangle: Gillespie County; No. 17, Dry Branch Quadrangle: Gillespie and Kerr Counties; No. 18, Klein Branch Quadrangle: Gillespie and Kerr Counties, *Bureau of Economic Geology*, University of Texas, Austin 12, 75¢ each, July 1954.—Continuation of the series of 7½-min maps in the Texas Llano uplift area. They are in color on a scale of 1:31,680 and each has an accompanying text.

Capital and Output Trends in the Mining Industries, 1870-1948, by Israel Borenstein, Studies in Capital Formation and Financing, Occasional Paper 45, *National Bureau of Economic Research Inc.*, 261 Madison Avenue, New York 16, N. Y., $1.00, 81 pp., 1954.—A study to discover what light past records might throw on future demand for capital in mining industries. *(See Trends P. 1161.)*

List of Geologic Publications and Maps of Indiana, compiled by Gerald S. Woodard, *Indiana Geological Survey*, Bloomington, Ind., free, 66 pp., 1954.

Minerals Yearbook 1951, prepared by the staff of the U. S. Bureau of Mines, Paul W. McGann, editor, Robert E. Herman, assistant editor, Superintendent of Documents, *U. S. Government Printing Office*, Washington 25, D. C., $5.25, 1694 pp., 1954.—A reference summary of a record year for U. S. mineral industry; the gross number of mining firms remained constant at 34,100; anthracite consumption declined moderately, but annual apparent consumption of most minerals increased over 1950; mineral-manufacturing industries had the highest sales, inventories, and orders in history.

Practical Refractometry by Means of the Microscope, by Roy M. Allen, *R. P. Cargille Laboratories Inc.*, 117 Liberty Street, New York 6, N. Y., $1.00, 76 pp., 15 figs., 1954.—Written especially as a guide and an aid to users of Cargille's Index of Refraction Liquids for Microscopy, but also useful to workers in the field of microscopical identification of minerals and other solid substances.

(See also page 1144)

Books for Engineers

ORDER YOUR BOOKS THROUGH AIME—Address Irene K. Sharp, Book Department. Ten pct discount given whenever possible.

Copper, edited by Allison Butts, *Reinhold Publishing Corp.*, $20.00, 936 pp., 1954.—Subtitled *The Science and Technology of the Metal, Its Alloys and Compounds*, the book is Monograph 122 in the ACS series. Almost every phase of the chemistry and metallurgy of copper, its alloys and compounds, is covered. The 46 chapters are each written by a specialist in his field. They cover all important fundamental principles, latest practices in the industry, and many of the less well-known applications of copper.

Compressed Air Handbook, *McGraw-Hill Book Co. Inc.*, $8.00, 418 pp., 2nd ed., 1954.—The material in this handbook is divided in six sections covering applications in a variety of industries; portable tools and rock drills; the compressed air system; positive-displacement compressors; dynamic-type blowers and compressors; and engineering data and test procedure. The book is designed as a reference manual on the theory, selection, application, installation, testing, and maintenance of pneumatic material. Well illustrated.

Atomic and Free Radical Reactions, Volumes I & II, American Chemical Society Monograph, No. 125, by E. W. R. Steacie, *Reinhold Publishing Corp.*, $28.00, 2 vol., 901 pp., 2d ed., 1954.—The first volume is a general discussion of experimental methods and of the role of atoms in thermal and photochemical reactions, and also presents a systematic survey of data pertinent to the rates of individual elementary reactions. The second volume deals with specific elementary reactions of systems containing carbon, hydrogen, oxygen, nitrogen, chlorine, bromine, iodine, sodium, other metals, and sulphur. Reaction index and an extensive bibliography are included.

Rare Metals Handbook, edited by Clifford A. Hampel, *Reinhold Publishing Corp.*, $12.00, 657 pp., 1954.—Assembled for the first time in one handy source is the latest information on more than 35 less common metallic elements, previously little investigated but now playing an increasingly important role in modern technology. Information about each element is arranged for quick reference to such aspects as occurrence, production statistics, economics, derivation, physical and chemical properties, fabrication techniques, alloys, and application.

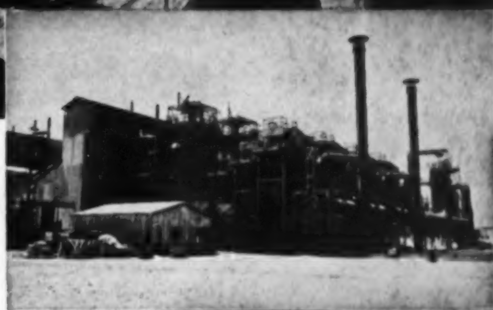
Minerals for Atomic Energy, by Robert D. Nininger, *D. Van Nostrand Co. Inc.*, $7.50, 367 pp., 1954.—A guide to exploration for uranium, thorium, and beryllium by the deputy assistant director for exploration of the Atomic Energy Commission. Part I describes the minerals and mineral deposits that are sources and potential sources. Part II is a comprehensive survey of the various areas of the world with respect to their favorability for new deposits of atomic energy minerals, with particular attention to the U.S. Part III covers prospecting equipment and techniques, the use of the Geiger and scintillation counters, evaluation of deposits, and details of prices, markets, and governmental controls. Extensive appendices include mineral identification tables, classifications of ore deposits, testing and analysis procedures, equipment suppliers, analysis centers, and laws and regulations controlling prospecting here and abroad. Illustrations in color and in black and white.

Coal, Its Formation and Composition, by Wilfrid Francis, *Edward Arnold Ltd.*, London, available in the U.S. from St. Martin's Press Inc., $17.50, 567 pp., 1954.—A well-illustrated, comprehensive, and systematic presentation of value to fuel technologists in technical universities, research institutions, or in the Government. The author, a consulting chemist and fuel technologist, has studied and worked with leading British and U.S. authorities.

Valuation of Alluvial Deposits, by H. L. H. Harrison, *Mining Publications Ltd.*, London, 45s., approx. $6.50, 308 pp., 2nd ed., 1954.—Originally published in 1945 under the title *Examination, Boring and Valuation of Alluvial and Kindred Ore Deposits*, this book has been considerably revised and contains much additional information and data "to assist the engineer to prepare closer estimates called for in the case of low-grade alluvials which will form the ore reserves of the future in mining fields where keen competition has already alienated the higher-grade ground."

Seismicity of the Earth and Associated Phenomena, by B. Gutenberg and C. F. Richter, *Princeton University Press*, $10.00, 310 pp., 1954.—Evaluates the present relative seismicity of various parts of the earth, and discusses geographical and geological relations of the principal earthquake zones and areas. There are tables of earthquakes and earthquake activity, a list of active volcanoes, and a bibliography. In this revision, minor textual changes have been made, some new material has been supplied as addenda, and most of the tables have been extended chronologically.

(See also page 1142)



Anaconda First to Roast Low Grade Sulfur Ore to produce SO_2 for Acid Manufacture

The world's first commercial installation for producing SO_2 gas from low grade sulfur ore, is now on stream at Anaconda Copper Company's plant at Weed Heights, Nevada.

The FluoSolids System that makes this possible includes four 18 ft. dia. Reactors plus other Dorr and auxiliary equipment. SO_2 gas is sent to a 450 TPD contact acid plant which supplies all acid requirements for leaching 11,000 tons of copper ore per day.

Feed to the system is 650 to 750 tons per day and gas production 26,000 to 30,000 C.F.M. Gas strength averages 8 to 12% representing a sulfur recovery of 98%. Unusual? Yes, because this is the first time that low grade sulfur ore could be recovered as SO_2 . . . economically. Here's how the system works . . . ore averaging 28% total sulfur is crushed to 10 mesh and fed dry to the Reactors which operate in parallel. Once ignition temperature is reached no extraneous fuel is needed. Ore is simply fed in at the design rate, latent heat in the bed immediately brings it to ignition temperature, and the fluidizing air oxidizes the sulfur to SO_2. Shutting down is a matter of minutes. And because the fluid bed stores sufficient heat, roasting can be started again after as much as 72 hours without adding additional fuel.

If you would like more information of FluoSolids . . . the most significant advance in roasting technique in the last 30 years . . . write The Dorr Company, Stamford, Conn., or *in Canada*, The Dorr Company, 26 St. Clair Avenue, East, Toronto 5.

FluoSolids is a trademark of The Dorr Company, Reg. U.S. Pat. Off.

Better tools TODAY to meet tomorrow's demand

DORRCO

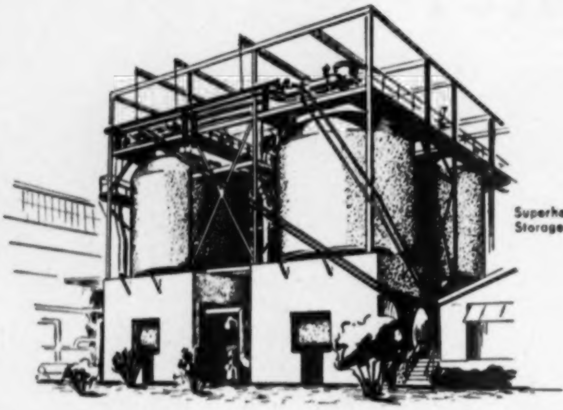
FIFTY YEARS 1904-1954

DORR

WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT

THE DORR COMPANY • ENGINEERS • STAMFORD, CONN.

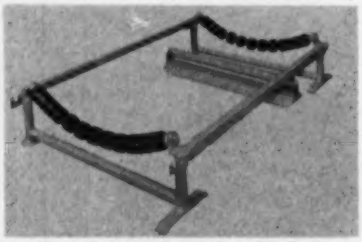
Offices, Associated Companies or Representatives in principal cities of the world.


Superheated Water
Storage Tanks

Manufacturers News

Flexible Idler

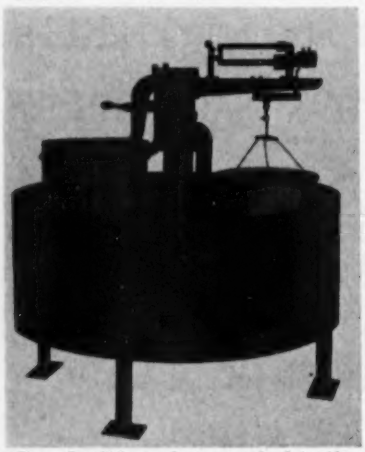
A cable suspension idler for belt conveyors, offered by *Joy Mfg. Co.*, provides a load conforming catenary, cushions the belt in handling bulk material. The Limberoller uses only



two bearings and carries the belt on resilient, pressure molded neoprene disks, all revolving at the same speed. Stands for the Limberoller are assembled into special conveyor sections. **Circle No. 1.**

Float-Sink Testing

Robert Holmes & Bros. Inc. has added a float-sink testing machine to its line of sampling and testing equipment. This dual tank model



offers flexible and economical testing with inexpensive media. Savings in time, labor, and material are offered over hand methods. **Circle No. 2.**

Portable Weigher

Transportofeeder that can be moved to various plant location is latest item from *Dwight-Lloyd Inc.*, div. of Sintering Machinery Corp. New machine is a portable, self-contained, continuous weighing scale complete with belt conveyor and drive. One model has 18-in. belt for handling 16 tph. **Circle No. 3.**

Uranium Ore Analysis

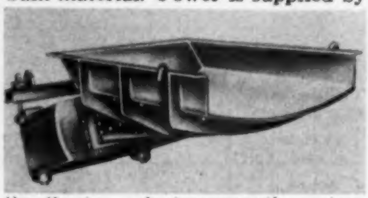
Sherwin Instrument Co. has available a portable laboratory for on-the-spot uranium analysis of ore samples. No special training is required to use the kit. **Circle No. 4.**

Rotary Rock Bit

An insert rock bit for better rotary drilling in mineral exploration has been developed by *Herb J. Hawthorne Inc.* The bits feature a special welding process to prevent the inserts loosening from the bit, and are built with the patented Hawthorne interchangeable, replaceable blade design. **Circle No. 5.**

Heavy Duty Feeder

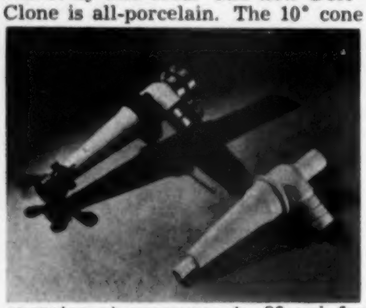
A new heavy tonnage vibratory feeder, model F-86, is the largest in a complete line announced by the *Syntron Co.* The feeder is equipped with a 54x72-in. flat pan trough for a maximum capacity of 750 tph on bulk material. Power is supplied by



the Syntron electromagnetic system operating at 3600 vibrations per min on 220 or 440-v, 60-cycle ac current. Rate of flow is controlled by a dial switch, and the feeder may be supplied with multiple driving magnets for greater tonnage and wider stream of material. **Circle No. 6.**

Porcelain Cyclone

Dorr Co. has announced a type P50 cyclone for separations in the 10 to 20 micron range on nonabrasive, relatively fine feed. The new DorrClone is all-porcelain. The 10° cone



operates at pressures to 80 psi for maximum flow of 30 gpm. Heat and corrosion resistance specially adapt this model for difficult applications. **Circle No. 7**

Shaft Equipment

Mayo Tunnel & Mine Equipment, may be the firm you are looking for —if the aim is a headframe or skip for that new hole in the ground. Mayo specializes in headframes, skips, cages, gilleys, and jumbos. In short, special equipment for tunnels and shafts. Designs are available for both shallow and deep shafts. **Circle No. 8.**

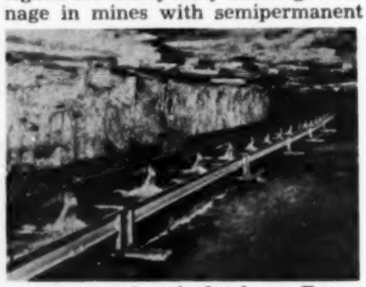
Lightweight Feeder

With capacity in excess of 300 tph, *Barber-Greene's* Redi-Flow mechanically vibrated feeder is termed lightweight and low cost. The 20 and 26-in. width units feed 24 and 30-in.

conveyor belts, averaging 200 tph capacity for the smaller one, and 300 tph for the 26-in. **Circle No. 9.**

Underground Conveyor

A new underground belt conveyor announced by *Jeffrey Mfg. Co.* is designed for heavy duty and high tonnage in mines with semipermanent



or permanent main haulage. Frame is built for 30 to 48-in. belt widths, and head section takes motor drives to 160 hp. **Circle No. 10.**

Faster Filtering

A large Canadian mining company has already had Tween 81, *Atlas Powder Co.'s* filtering aid, in commercial use for a year. This complex surface active agent is reported to reduce moisture content and to markedly improve filter cake characteristics. **Circle No. 11.**

Hydraulic Giant

"First revolutionary improvement in hydraulic mining in 90 years," is strong claim marking introduction of *Chiksan Intelli-Giant*. Major feature is stabilization without counterweights. Operator can sit at hydraulic controls and regulate pressures from 30 to 300 psi, with horizontal traverse of 320° and vertical coverage of 120°. Eight years of development are said to be backed up by tests from Alaska to California. **Circle No. 12.**

Free Literature

(21) EYE PROTECTION: *Mine Safety Appliances* Co. has a new Skullgard eyeshield for convenient cap-mounting on all types of MSA Skullgard protective headgear. Formed plastic device offers un-

obstructed vision and deflects flying particles, hazardous to workers' eyes. Hinged at the peak of the Skullgard, it will remain firmly in either the up or down position.

(22) REFRACTORY SELECTION: Prepared mainly as a review of practical refractory problems and their solution, *Basic Refractories'* "A Guide For Refractory Selection" also discusses nomenclature generally applied to the various classes and types of granular refractories, outlining their characteristics and properties. Applications in both open hearth and electric steelmaking furnaces are covered, as well as gunning and ramming techniques.

(23) LABORATORY TESTING: *Western Machinery Co.* has a 4-page, illustrated bulletin on laboratory testing of process methods for metallic and nonmetallic ores, coal, sand, and gravel. The practical necessity for laboratory testing and Wemco's laboratory test service are described, along with an analysis of typical process problems.

(24) SHUTTLE CARS: *Goodman Mfg. Co.'s* bulletin No. 5411 is devoted to Goodman cable reel shuttle cars. Among features listed are: specially designed motors; safe electrical control; four wheel drive, steering, and brakes; easily adjusted discharge height; hydraulically controlled cable reel; zone lubrication.

(25) CYCLONE: *Heyl & Patterson* has a 20-page illustrated booklet on the H&P cyclone for slurry thickening, classification, clarification, and recovery of suspended solids. Given are available sizes and uses and typical applications for the coal industry, metallic and nonmetallic mining, and chemical processing.

(26) MERCURY RECOVERY: Practical ore dressing principles are applied throughout *Denver Equipment Co.'s* "Flowsheet for Mercury Recovery" to solve milling problems and to produce a high recovery of high grade concentrate suitable for retorting.

(27) OXYGEN MEASUREMENT: *Minneapolis-Honeywell Regulator Co's* data sheet No. 10.15.11 describes the application and operation of the A. O. Beckman model F-3 oxygen analyzer and Brown ElectroniK recorder for measurement of oxygen in industrial processes.

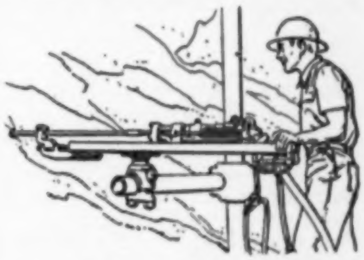
(28) FURNACE BELTS: Bulletin from Electro-Alloys Div., *American Brake Shoe Co.*, on conveyor belts for heat-treating furnaces describes the manufacture and testing of Thermalloy belts. Drawings show how staggered link design eliminates crank-shafting and evens the load.

(29) BULK PNEUMATIC HANDLING: *Fuller Co's* "How to Pull Dollars Out of Thin Air" tells how handling costs can be reduced substantially by using the proper pneumatic handling system.

(30) ALUMINUM SIDING: *Alcoa* now offers a ribbed aluminum siding designed to improve the appearance of low cost industrial buildings. Intended primarily for use on frame type structures, it can also be used as a facing sheet on concrete block buildings. It is available in 0.032-in. thickness and from 5 to 18-ft lengths in 6-in increments.

(31) CUTTING & WELDING: *Air Reduction Sales Co.'s* condensed 52-page catalog covers gases, welding and cutting equipment and accessories, torches, tips, and regulators. It also includes three of Airco's latest developments: Aircospot (inert-gas spotwelding), Easyarc 12 electrode, and the new heavy duty cutting attachments for torches.

(32) DEEPHOLE DRILLING: *Gardner-Denver* has compiled actual job reports on deephole drilling with percussion rock drill in a 24-page booklet. Varied uses of longholes for vertical and horizontal ring drilling, pillar recovery, exploration and sampling, and block caving are covered,



and one section outlines latest G-D machines for longholing, including the big 4 and 4½-in. drills. *(Ed. Note: This is one of the most handsome, informative, and clearly illustrated manufacturers' booklets we have seen.)*

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after March 15, 1955 — if mailed in U. S. or Canada

Please send me { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	Students should write direct to manufacturer.						

Name..Title..............

Company..

Street...

City and Zone.......................................State.............

(33) CONTINUOUS ELEVATORS: An 8-page bulletin illustrates *Humphrey Elevator Co.'s* Manlift elevators to provide simultaneous up and down employee transportation with no waiting or delay. Suggested applications include multistory buildings with vertical processing, or where frequent inspection of machinery on various levels is required.

(34) BALL VALVES: *S. Morgan Smith Co.* has an 8-page brochure on its new line of manually operated ball valves, now offered in sizes from 12 to 48 in. for shut-off service at pressures up to 150 psi for water works and industrial applications.

(35) INDUSTRIAL ROOFING: *Toledo Porcelain Enamel Products Co.'s* illustrated booklet describes uses of V-Corr, an enamel-on-steel roofing and siding material. Made from a corrugated steel base to which porcelain has been fused at 1550°F, it offers "complete protection against fire, corrosive gases, moisture, steam, and salt air."

(36) COAL STRIPPING: Available from *Harnischfeger Corp.* are reprints of "Raising Strip-Mine Life," a "Coal Age" article that describes the P&H model 1855. This is the first machine ever built with P&H Magnetorque units for all operating functions—digging, hoisting, swinging, and travel.

(37) MAGNET WIRE: Illustrated with charts, tables, drawings, and photographs, *Anaconda Wire & Cable Co.'s* 84-page catalog C-79-12 contains up-to-the-minute information on magnet wire.

(38) pH CONTROLS: *Bristol Co.'s* 38-page bulletin Q1304 covers instrumentation for pH measurement and automatic control. Shown are drawings and photographs of Bristol instruments in such processes as copper and tungsten ore flotation, Heavy Media separation, as well as general application illustrations in the chemical, petroleum, and water treatment fields.

(39) MAGNETIC SEPARATION: Bulletin B-1500 from *Dings Magnetic Separator Co.* covers wet magnetic separators for taconite and magnetite ores, standard and cyclone Heavy-Media circuits, roasted ores, pyrrhotite, and beach sands. Features stressed include: heavy duty construction, cooler operation, and ample motor capacity to meet peak loading conditions.

(40) LEAKAGE: In a year, a 1/32-in. leak steals 95,040 gal—16 railroad tank cars full. Bulletin from *Surveys Inc.*, maker of packing and sealing

compounds for process and heating, tells how to fight this robber.

(41) DIAMOND DRILL BITS: *Diamond Products Inc.* has a 19-page bulletin on diamond drill bits showing the craftsmanship and diamond quality involved and the results. Also explained is Drillco resetting service.

(42) STRIP MINING: "Stripping for Metals" contains more than 15 photographs of *Caterpillar* machines engaged in mining jobs. Large rubber-tired scrapers are pictured stripping off overburden and crawler tractors are shown as "strip mine workhorses" in such varied jobs as stockpiling and cleaning up after boom-type excavators.

(43) PERSONNEL TESTS: A catalog from *Science Research Associates*, publishers of tests and employee relations material, contains general and specialized tests for clerical, office, shop, and factory employees. A morale test also measures the feelings of employees about their jobs, their pay, and the company they work for.

(44) RECTIFIER-TYPE WELDER: *General Electric's* GEC-1267 describes the new 300-amp, NEMA-rated, rectifier-type welder featuring quiet operation and low maintenance cost. A current range of 20 to 375 amp is provided by the moving primary coil design.

(45) AIR COMPRESSOR: *Le Roi's* 105 cfm Utility air compressor is back on the market following heavy demand for a unit of its easy portability. Installation drawings show the width is 25 in. and the overall length is only 82 in.

(46) CATALYSIS RESEARCH: *Battelle Institute's* "Research in Catalysis and Other Phases of Surface Chemistry" describes how Battelle has solved other companies' problems "efficiently, economically, and immediately."

(47) FREEZEPROOFING: *Calcium Chloride Institute's* "Freezeproofing Coal with Calcium Chloride" contains recommended procedures for treating winter shipments of coal and other minerals.

(48) CERAMIC COATINGS: *Armour Research Foundation* of Illinois Institute of Technology has a brochure on the "Solution Ceramics" process. Among possible uses is for upgrading the surface of refractories.

(49) GAS & AIR EQUIPMENT: *Roots-Connersville Blower* has issued a booklet commemorating its "hundred years of growing." This company recently added the Spiraxial compressor to its line of pumps, inert gas generators, and centrifugal blowers and exhausters.

(50) PROTECTIVE COATINGS: Magic-Vulc, used for protection of equipment from corrosion and abrasion, is covered in a revised catalog from *Magic Chemical Corp.*

(51) POLY-V DRIVE: Brochure 6638 explains design characteristics of *Raybestos-Manhattan's* single, endless belt with molded lengthwise ribs. Among the 14 specific advantages claimed for the Poly-V drive are: increased drive capacity, 50 pct more hp, shorter centers, and reduced inventories.

(52) RUGGED NUCLIOMETER: For details of *Stratex Instrument Co.'s* Bismuth Nucliometer. See page 1134.

(53) DRYERS, KILNS, COOLERS: For bulletin 16-D-2 on *Hardinge Co.* Ruggles-Coles rotary dryers, kilns, coolers. See page 1134.

(54) AIRLEG-DRILL UNIT: For *Cleveland Rock Drill Div.'s* bulletin RD-30. See page 1137.

(55) SINTERING: For *Dravo Corp.'s* bulletin 1503 on Dravo-Lurgi sintering equipment. See page 1139.

(56) GRINDING FACTS: For *Traylor's* bulletin 8121. See page 1147.

FIRST CLASS
PERMIT No. 6433
Sec. 34.9 P.L.&R.
New York, N. Y.

BUSINESS REPLY CARD
NO POSTAGE STAMP NECESSARY IF MAILED IN THE UNITED STATES

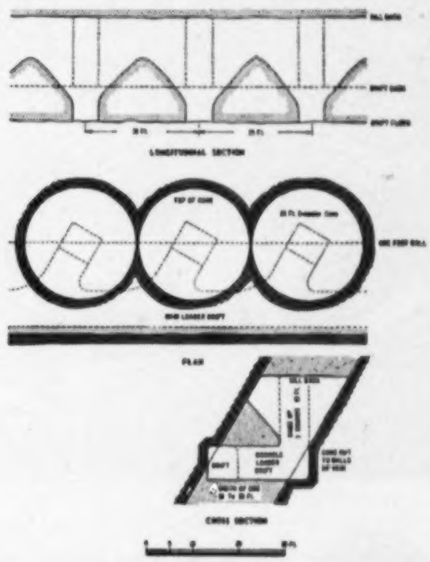
3c.—POSTAGE WILL BE PAID BY—

MINING ENGINEERING

29 WEST 39th STREET

NEW YORK, 18, N. Y.

INCREASE PRODUCTION LOWER COSTS



Yes! You can increase production and lower costs by using Eimco loaders to load your production tonnage.

The advantages of being able to load larger pieces, use less powder, practically eliminate secondary blasting and absolutely eliminate expensive chutes and grizzlies, will enable your mine to get into production in a new area faster at less expense.

That's why so many mining men are traveling to see mines that have changed their systems to production loading with Eimcos.

Many different ideas for saving time and lowering costs have been developed by operators to fit their particular conditions. A sketch of one of these is at right. Eimco engineers have helped work out numerous systems, they will be glad to help you. Write Eimco for information.

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

New York, N. Y. Chicago, Ill. San Francisco, Calif. El Paso, Texas Birmingham, Ala. Duluth, Minn. Kellogg, Ida. London, Eng. Paris, France Milan, Italy

E79

You Can't Beat An Eimco

AMERICAN METAL Co. announced discovery of a copper-lead-zinc ore deposit in the Little River Lake area of northeastern New Brunswick about 35 miles northwest of Newcastle. Drilling has been going on in an area about 6 miles long and 4 miles wide since June 17. A deposit of about 3 million tons averaging 0.5 pct copper, 4.5 pct lead, and 10.5 pct zinc, and about 1 million tons of ore averaging 1.9 pct copper, 0.1 pct lead, and 0.5 pct zinc. Ores also contain some gold and silver. The deposits are about 15 miles south of Bathurst area discoveries. The Little River orebodies were found by aerial surveys conducted for American Metal by International Nickel Co. of Canada Ltd. International Nickel will have a 25 pct interest in profits.

Metals purchases by the Defense Dept. for the fourth quarter are running about half of the first and second quarters of 1954 and slightly less than that of the third quarter.

PRESIDENT EISENHOWER has approved a proposed $8.5 million Federal aid program for prevention of surface water floods in anthracite mines. The program will be presented to the next Congress and will require an appropriation. It is contingent upon Pennsylvania contributing at least an equal sum and assuming responsibility for the operation.

Reorganization of the health, safety, and coal mine inspection activities of the U. S. Bureau of Mines will separate them from other pursuits of the USBM. Separation was recommended recently by a survey team. The change is expected to be about Jan. 1, 1955.

THE ATOMIC ENERGY COMMISSION has signed a contract with Climax Uranium Co. for construction of an addition to the uranium ore processing plant at Grand Junction, Colo. Substantial increase in plant capacity is expected when work is completed in about nine months. The plant is operated by Climax Uranium.

POTASH CO. OF AMERICA will soon have the longest conveyor system in the U. S. at its Carlsbad, N. M., operations. The present underground 5800-ft conveyor system will be extended to approximately 7¼ miles. Hewitt-Robins Inc. has been awarded the contract. The longest system currently operating is one 5½ miles long in a western Pennsylvania coal mine.

FREEPORT SULPHUR Co. has been discussing plans with Pittsburgh Consolidation Coal Co. for the development of a commercial potash deposit in the Carlsbad, N. M., area. If an agreement to build the $60 million plant is reached, production is expected to reach about 245,000 tons of K_2O. Freeport has been drilling at the proposed mine site for more than three years. It will take two to three years to complete facility construction.

Union Miniere du Haut Katanga, Belgian owners and operators of the Shinkelobwe uranium mine in the Belgian Congo, is the first company outside the U. S. to join the Atomic Industrial Forum Inc. The forum is an American industrial forum devoted to advancement of peacetime use of atomic energy.

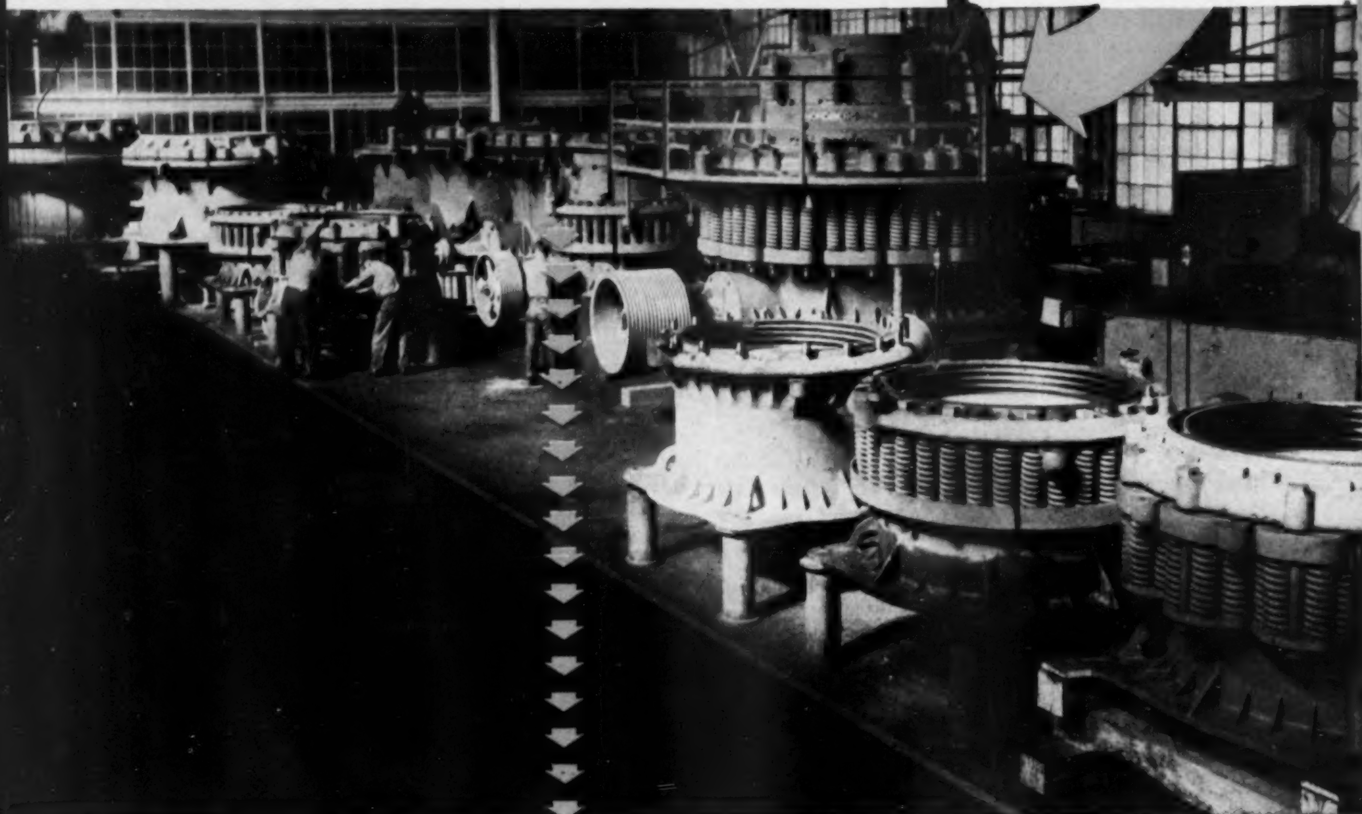
SOUTHWESTERN ENGINEERING Co. has been awarded a contract for the installation of a Heavy-Media separation plant for Fluoruros S. A. in Spain. The plant will be part of a $1 million development and will produce acid grade fluorspar in north central Spain. The plant will have an estimated capacity of 400 tpd.

One year after Foote Mineral Co.'s $4 million Sunbright, Va., plant went "on stream," the company reports that the second wave of lithium expansion is nearing the tuning up stage. The Kings Mountain, N. C., spodumene mine and concentrating facilities have already been expanded, with substantially higher production effective October 1.

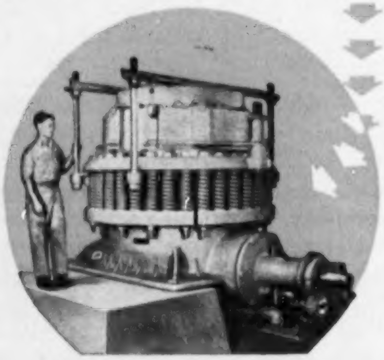
THE SOUTH AMERICAN GOLD & PLATINUM Co., dredging operators in Colombia, have acquired more than one third of the capital stock of Pato Consolidated Gold Dredging Ltd., Pato, also operating in Colombia, sold South American Gold & Platinum about 1.2 million of its 3,502,500 outstanding shares. South American Gold & Platinum now has the right to name three of the six directors of Pato.

AMERICAN POTASH & CHEMICAL CORP. has completed plans for construction of a plant for the manufacture of lithium chemicals near San Antonio, Texas. The plant will be owned by a newly formed company, American Lithium Chemicals Inc., with 50.1 pct of the stock owned by American Potash & Chemical. The balance is held by Bikita Minerals (Private) Ltd. Ore for the plant will come from Bikita Minerals operations in Southern Rhodesia. American Potash already holds 21.5 pct interest in Bikita. Selection Trust Ltd., London, is responsible for the technical management of Bikita, in which they and associates hold 50 pct. The other principal stockholder in Bikita is American Metal Co.

Here's the 5000th SYMONS®



... and here is SYMONS CONE CRUSHER No. 5001 ... built for one of the world's outstanding Slag Producers



With the 5,000th SYMONS CONE CRUSHER completed, production on Number 5001 was well along . . . a 4' standard crusher scheduled for delivery to one of the world's largest slag producers—who have installed a total of 63 SYMONS CONE CRUSHERS for the dependable, profitable crushing of huge tonnages of slag.

This installation points up the important fact that a large proportion of all SYMONS CONES in service are repeat orders *from satisfied users. For example, here are just a few fields in which SYMONS CONES are used, and the number of repeat orders placed by* single *users in each field:*

ASBESTOS	18	IRON	32
ABRASIVES	16	LEAD-ZINC	24
CEMENT	6	MOLYBDENUM	18
COPPER	41	NICKEL	28
FELDSPAR	15	NITRATE	11
GOLD	8	REFRACTORIES	12
GRAVEL	18	STONE	39

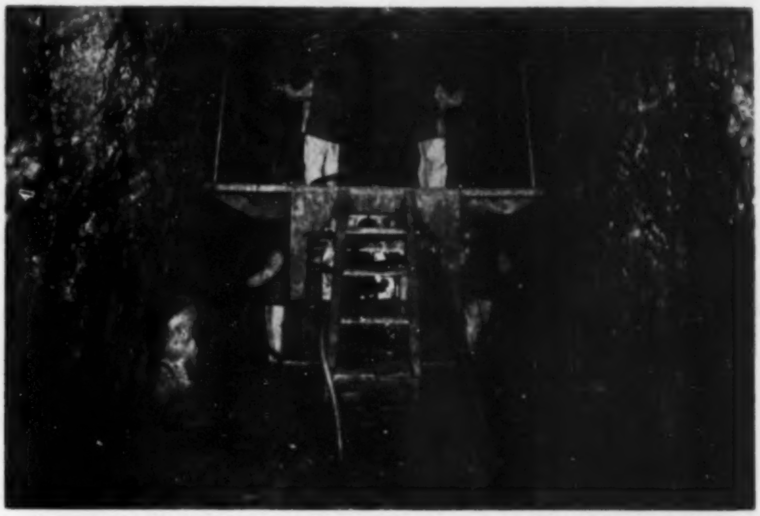
SYMONS GYRATORY CRUSHERS · NORDBERG GRINDING MILLS · NORDBERG KILNS AND COOLERS · NORDBERG MINE HOISTS · SYMONS VIBRATING GRIZZLIES AND SCREENS · NORDBERG DIESEL • DUAFUEL® and SPARK-IGNITION GAS ENGINES

Five Air Leg Drills on One Carriage Drive INCO Haulageway

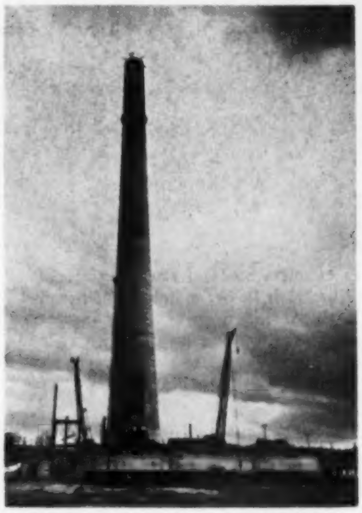
International Nickel Co. used a specially designed drill carriage mounting five air leg drills to complete the driving of a main haulage way. Simultaneous operation of five drills permitted high speed drifting between shafts at the Levack mine.

The special drill carriage used at the Sudbury district operation in Ontario was designed and built by Inco's mines dept. The rig has been so successful that Levack mines once completed 28 ft of drilling and blasting in 24 hr. The machine folds up for convenient removal during blasting.

Driven on the 2650 level, the big haulage way is 11 ft wide and 12 ft high to accommodate 20-ton locomotives and 260-cu ft cars. Miners have averaged better than 300 ft per month and one month topped 400 ft in driving the 3000-ft tunnel. Rounds are drilled and blasted before lunch. Smoke is cleared during lunch through ventilation lines by exhaust fans. Following lunch, crew members proceed with mucking operations while one man makes repairs and services the drill carriage. The new haulageway will accommodate 20-ton locomotives.

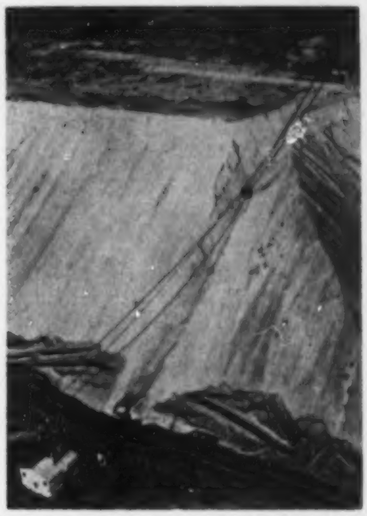


International Nickel Co.'s new carriage carrying five air leg drills works during drive to complete main haulage way between two shafts. Four drill operators can be seen clearly but fifth man is almost completely hidden by carriage.



Steel work for International Nickel Co's iron ore plant near Copper Cliff, Ont., has started. The new 637-ft chimney, largest in the British Commonwealth, is seen in the background. The plant will use an ammonia leaching process developed by Inco. Process operates at atmospheric pressure.

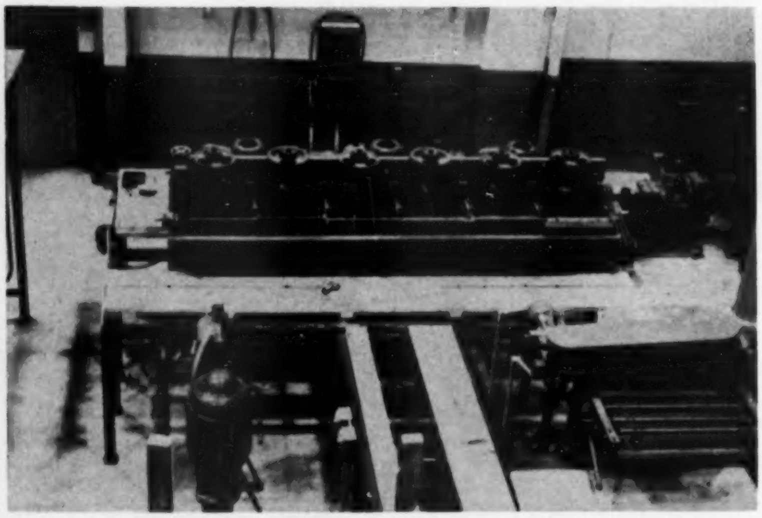
H. W. Heckt, export manager of Denver Equipment Co., speaks to 19 technical experts from 10 European countries touring the U. S. on an FOA technical mission. In Denver, the group visited DECO's Ore Testing Div. and the Colorado School of Mines Research Center at Golden. Gerard Lally of the Foreign Operations Administration, Washington, D. C. escorted the group.



This tower excavator installed by Sauerman Bros. Inc., is believed to be the largest single unit made for sand and gravel operations. Unit handles 450 cu yd per hr for a West Coast supplier on an average haul of 300 ft.

Penn State Mineral Preparation Lab Rivals Commercial Units

One of the outstanding physical plants for the study of mineral preparation on the laboratory level in a U. S. university or college has been assembled at Pennsylvania State University. The facilities even rival those of commercial research organization, according to H. B. Charmbury and D. R. Mitchell in *Mineral Industries*, Penn State publication. Professor Charmbury is head of the dept. of mineral preparation and Professor Mitchell is chairman, Div. of Mineral Engineering at the university.

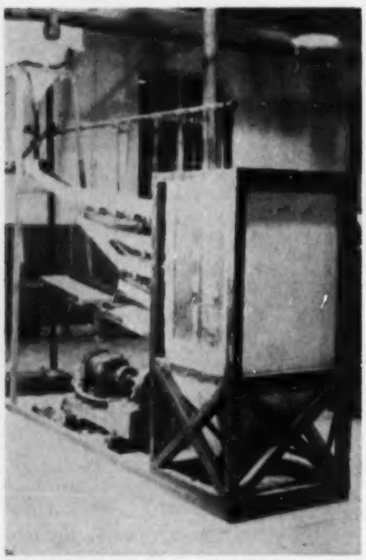


Froth flotation equipment is exemplified by two complete banks of small commercial subaeration flotation machines. Feed is prepared by 3x3-ft Denver agitator conditioner. Reagents are metered to the conditioner and to the cells by a set of Denver reagent feeders. Denver No. 8 Mineral cells comprise one bank for handling metallic ores, while another bank of two Denver No. 8 Lasseter type cells is used for coal flotation. The six cell unit is shown above with the two cell unit underneath.

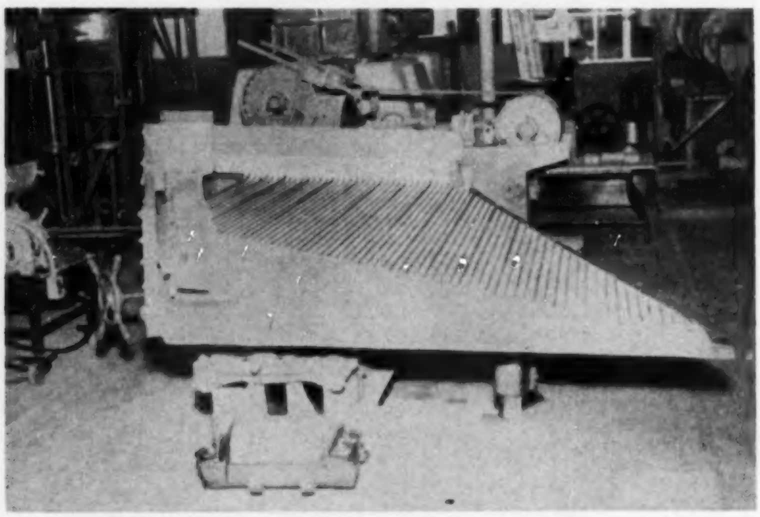
This Chance sand cone is available for testing low specific gravity materials. Sand reclamation apparatus is an integral part of the unit.

The opening of the mineral preparation laboratory has made it possible to undertake all phases of beneficiation study from highly theoretical small-scale research endeavors to large-scale pilot plant operations. Located in a wing of the Mineral Sciences Bldg., the laboratory was built at a cost of about $150,000 and houses another $150,000 worth of equipment. Some 3000 sq ft of floor space accommodates the equipment, with additional space for offices, a chemical control laboratory, special equipment, and a repair shop.

Existing facilities in the Mineral Sciences and Mineral Industries Buildings comprise what has been termed "an outstanding physical plant for instruction, research, and plant testing," by Professors Charmbury and Mitchell.



Coal beneficiation studies are carried out with the aid of this free discharge rheolaveur unit.



Gravity type concentration equipment outnumbers chemical and electric separation equipment. There are seven gravity type machines, including this half-size Deister concentrating table for wet concentration.

New Jersey Zinc Voice Communication Improves Cage Operation

Voice communication between man cages and hoist engineers installed at three New Jersey Zinc Co. mines has paid off in dividends of safety, time, and control.

Now that the cage can figuratively be stopped on a dime a lot of time is being saved. Before HoistPhones were installed at the Franklin and Sterling mines in Sussex County, N. J., and the Friedensville mine near Bethlehem, Pa., the cage could not be stopped once a destination had been set. With the hoist engineer in constant direct communication with the moving cage, extra trips are things of the past. The cage can be stopped or started from any place in the shaft, with an accompanying advance in speed and efficiency in emergencies and during shaft inspections and repairs.

Voice communication insures starting of the cage only after every man is aboard. Before the Mine

Two MSA HoistPhone microphones and loudspeakers are provided on this double-deck cage of 65-man capacity in the Friedensville, Pa., mine. A third microphone outlet is available on the roof. The vertical shaft reaches a depth of 1250 ft.

Hoist Engineer George Pierce keeps in touch with a man cage via the HoistPhone arrangement at the Sterling mine. Loudspeaker above his head has variable volume control and can be operated under almost any conditions.

Safety Appliances Co. system was installed, a waiting period was mandatory before starting up to insure the last straggler getting into the cage before starting up.

The HoistPhones are designed to operate on a frequency modulated (FM) carrier wave of 115 kc. A variable sound control permits operation under all conditions.

The Sussex County mines operate through inclined shafts and the Friedensville mine through a vertical shaft. The Franklin-Sterling orebodies were known as far back as 1640. However, the Franklin mine is almost depleted. The Sterling mine is continuing as a zinc source.

About 160 minerals have been identified at the Franklin and Sterling mines. Only three are important —zincite, willemite, and franklinite. Ore was first mined from Franklin in 1848 and from the Sterling deposit sometime before 1852. The Friedensville development had a 50

As the cage operator transmits instructions over the HoistPhone, hoisting engineer Joseph Hampton controls movements of the cage at Friedensville, Pa., shaft. The transmitter is controlled by a foot switch.

HoistPhone equipment for the hoist engineer's console at the Friedensville mine is mounted in the room below the hoist. Chief electrician Peter Kozak checks tubes.

year history of sporadic development limited to prospect drilling and hydrologic study. Finally, in 1944 a decision was made to reopen the property despite excessive quantities of underground water. Lowering of ground water is in progress using numerous boreholes radiating into country rock and delivering to pump batteries at 418 ft and 600 ft.

The first housing project at Friedensville has been completed. It is expected that a total working force of 400 men will be needed for mine, mill, and services for a 2500 tpd production.

WHEN a man goes looking for uranium, be he Charles Steen, Vernon Pick, or anyone of 163 million other people, the decision itself is almost enough to put him in business. If he's lucky, persevering, and perhaps smart enough he may find a deposit. Up to now, life is on the rugged side—from here on in he has a mine. Financing, something between $10,000 and $50,000 can usually be dredged up in the region where the discovery was made. If the mine is small enough he can work it himself. Our lucky prospector has a market for his ore at a price he is certain of. Undoubtedly milling is part of the industry. But our prospector turned mine operator needn't bother with that. His mine is usually too small to warrant a mill in the first place.

So, let's look at the mill operator. According to Carroll Wilson, vice president and general manager of Metals & Controls Corp., and former Atomic Energy Commission general manager, the mill operator is the forgotten man.

He told an audience at the special meeting of the National Industrial Conference Board that "Uranium is coming out of the hidden recesses of the Colorado Plateau in tonnages undreamed of a short six years ago. But expansion of the next consecutive step in the atomic energy process—milling—is at a relative standstill."

Mr. Wilson emphasized the difficulties involved in uranium milling. Uranium occurs in many different minerals. "Even a single orebody may contain several varieties of minerals and a considerable range of other content in the ore, such as lime. . . . All these factors greatly complicate the metallurgical problem of processing these ores and achieving high and consistent recoveries of usable materials."

Uranium processing plants cost as much as $6000 to $10,000 per ton of daily capacity. Economic size is probably at a point above 200 tpd—meaning a couple of million dollars or more for plant construction.

It takes an orebody of at least 360,000 tons to provide a five-year ore supply which would permit amortization. Few orebodies of that size have been found on the Plateau. Mr. Wilson noted that it would be most coincidental if the discoverer of such an orebody happened to have the know-how and resources to build a mill. Getting a supply of ore to support the mill presents other difficulties. Owners of sufficiently large mines find that if they mine enough to provide a fair feed rate for the mill, they end up in an income tax bracket that insures Uncle Sam a fine income from the operation. The miner is tempted to "throttle back" production to a level where he has a personal income of about $25,000 per year.

Should the mill operator decide to buy a proven orebody he finds the price inflated by promoters and beyond his ability to pay. Another matter is the lack of a schedule of prices for a period of years ahead, as there is for the miner. Contracts are negotiated for uranium concentrates on the basis of production costs including amortization and a reasonable profit. Mr. Wilson asks, "What is a reasonable profit?"

Mill working capital, Mr. Wilson states, amounts to about $1 million for a little 200-ton mill. At this stage of technological development cost predictions are difficult to make. If the operator finds that he must go farther and farther for his ore supply or if cost estimates are based on low lime ores and as time goes on he must use high lime ore to finish his contract, he is in trouble.

Mr. Wilson is of the opinion that, "The pressure is on the AEC to make the 'reasonable profit' small. Congress and the public rejoice when an individual miner strikes it rich, even if the only customer is the Government. They scold, on the other hand, when any company big enough to enter the milling business makes a profit commensurate with the risks involved."

What can the AEC do to end the standstill to milling development? Mr. Wilson feels that one of two things will do the job. The first, that the Government should construct its own mills, he sees as the wrong direction. He wants Government to encourage private enterprise—and as far as he is concerned only one measure is needed. He wants the same thing that holds for mining, a schedule of published prices for concentrate firm until 1962. Prices would be based on an average grade of mill feed over a reasonable range of grades. No change in the law is required, Mr. Wilson feels. Only administrative action is needed.

◆◆◆◆◆◆

INSTEAD of building the usual company town, Alcan has started what Julian Whittlesey, one of the Kitimat planners, calls a "public town." Aluminum Co. of Canada has built some prototype housing and stores and may build more prototypes as time goes by. But these are soon sold. Alcan's work is "to open new land and assure that town development stays on the main track of the master plan." Mr. Whittlesey, writing in *Architectural Forum,* explains the difference between Kitimat as a "public town" and the traditional company town.

"No company, however powerful, could hope to order up and operate a complete town with all the auxiliary features. A public town is the converse of a company town. The problem is to cause the town to get built, to coax it, to organize, finance, govern itself, to set up taxes and credit." Kitimat is getting started that way, with private builders beginning to do most of the construction, but under controlled conditions.

Kitimat will stick to its master plan because of legal and operational forces included in the original planning. Despite the fact that the master plan is completed, the planning consultants, Mayer & Whittlesey, are retained to continue contact and to extend it to the British Columbia architects and engineers and to the municipal government.

Seventy-five families have already bought homes in Kitimat with between 300 to 400 expected by winter. Alcan is not renting. Homes are selling for about $14,000, with a down payment of $700. Canada's counterpart to the U. S. Federal Housing Administration, the Central Mortgage & Housing Corp., is granting first mortgages of $9360. Alcan assumes the balance of $3940 as a second mortgage. To bal-

ance out transportation difficulties and to encourage home ownership, Alcan is giving each worker who builds a monthly bonus of $2.85 per $1000 of home cost. Alcan will also buy the house back any time within ten years at predetermined depreciation rates.

◆◆◆◆◆◆

SINCE World War I mineral consumption has been lagging behind production, with the exception of the World War II period, according to Israel Borenstein. In a study for the National Bureau of Economic Research, Mr. Borenstein indicates that the situation in part reflects sweeping technological advances of a character different from those on which the early industrial advance was based.

He says in his book *Capital and Output Trends in the Mining Industries, 1870-1948* that in the earlier development of American industry, both consumption and production of minerals increased much more rapidly than the total output of goods and services in the nation. Increase of mineral production per $100 of gross national product was from $2.70 in the period 1880 to 1889 to $4.50 in the period 1910 to 1919. Technological changes resulting in material savings, such as increased efficiency in the use of coal and oil and greater use of scrap in manufacture of steel and other metals, accounts for the change after World War I.

Reason for the study was to uncover if the past could aid in the evaluation of capital needs of the future. Until a certain point in the past, increased capital was needed for every dollar of output. For mining as a whole in 1870, 70¢ worth of capital was needed for each dollar of production, until 1919 $2.30 was needed for every dollar of output. By 1948 the ratio dropped to $1.30.

The study makes no attempt to predict the direction of the ratio. It does point out that the increase in the ratio generally coincided with a period of rapid growth and declined during a slack period.

Since 1870, output per wage earner has increased, with the increase to 1929 brought about by adding capital per labor unit. After 1929 the increase in capital per labor unit has been moderate and in some mining fields a decline in the ratio has set in. Nevertheless, output per labor unit has grown vigorously. (*See Books p. 1142.*)

◆◆◆◆◆◆

SOME time ago Freeport Sulphur Co. announced the discovery of a tremendously significant nickel deposit in the Moa Bay district of Cuba. With the agreement recently signed between the General Services Administration and Freeport the first big step toward developing the orebody into a significant contributor to the free world nickel supply is about to be made. The new agreement provides for the construction and operation by the company of a pilot plant to study on a large scale the new process for production of nickel and cobalt from Moa Bay ores.

Financed by the Government, the plant will be located near New Orleans on land purchased by Freeport. The unit will treat 50 tons of ore per day supplied by Freeport without charge to the Government. Work will be done by Freeport at no charge. The pilot plant is expected to be the forerunner of a commercial size unit. Freeport has already been financing study of certain phases of the process which include techniques devised by Chemical Construction Co.

Along with the pilot plant agreement, another contract provides for Government purchase of nickel and cobalt from the commercial plant which Nicaro Nickel Co., Freeport subsidiary, is planning to build at the successful completion of the pilot plant program. The purchase contract is contingent upon the Government's decision to enter into the commitment at the end of the pilot plant program. Possible purchase would be 150 million lb of nickel and 15 million lb of cobalt at prevailing market prices by June 30, 1963.

Nicaro Nickel plans to use private funds for the commercial plant. Part of the plant and auxiliary facilities may be constructed near the Moa Bay deposits. The ore would be leached with sulphuric acid and intermediate concentrate produced. The concentrates would be sent to the U. S. for separate extraction of nickel and cobalt metal. Production capacity contemplated is 30 million lb of nickel and 3 million lb of cobalt metal annually. The Moa Bay deposit is reported to contain 40 million tons of ore averaging 1.35 pct nickel and about 0.14 pct cobalt.

◆◆◆◆◆◆

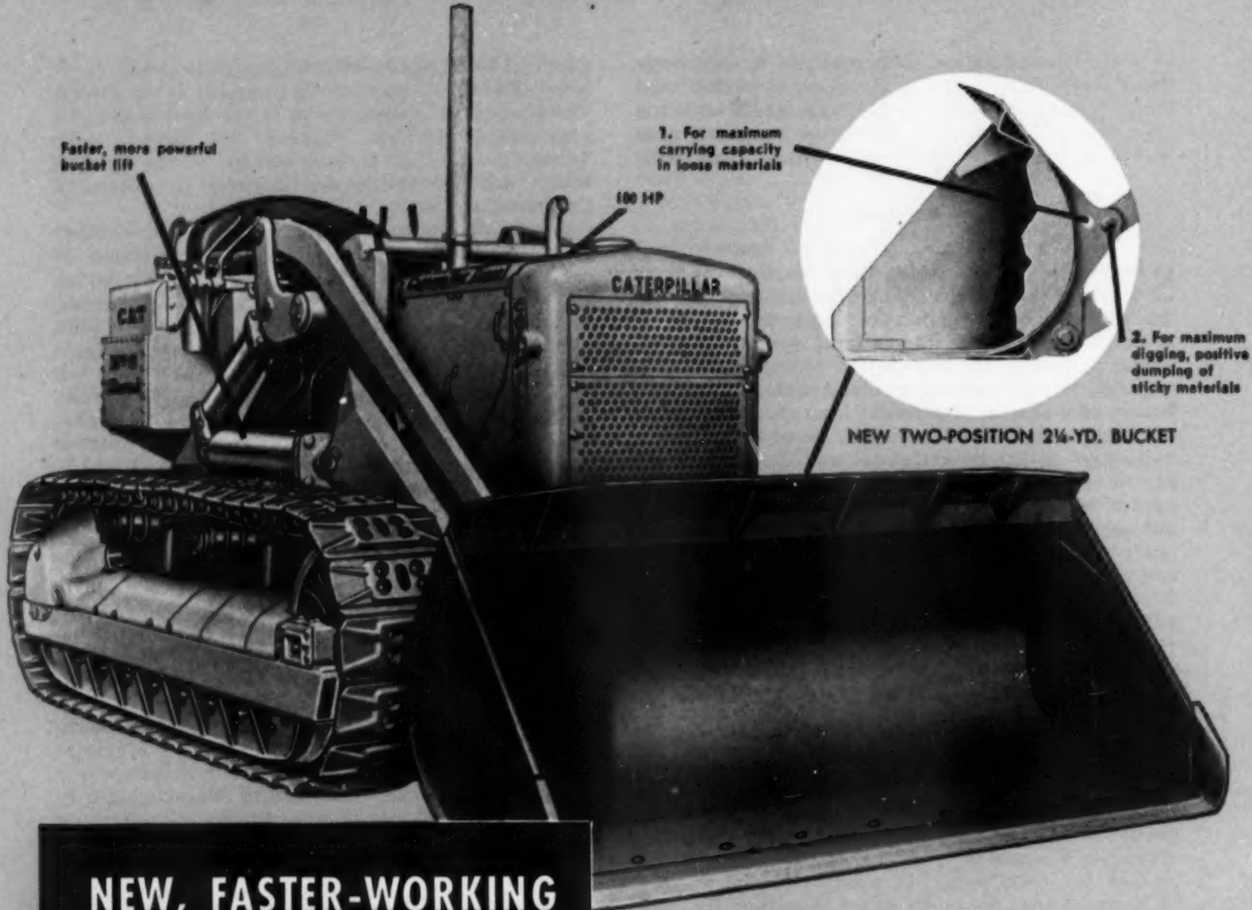
COLUMBIA University has opened what has been termed the world's finest geochemical laboratory. The Lamont Geological Observatory occupies an entire building designed to house the chemical analyzing and radiation detecting tools. J. Laurence Kulp, who is in charge of the laboratory and a geochemistry authority, predicts that among other things, the extension of radioactive carbon's range from 30,000 to 60,000 years ago. Carbon 14 is used extensively to date organic material—mummy wrappings, prehistoric bison remains from Alaska, and human bones.

Other atomic clocks provide a "kind of time spectrum" from the planet's beginnings to just a few years ago. The potassium clock is potentially the most valuable of these instruments. Common occurrence of potassium makes it ideal for dating this planet's older rocks back even 5 billion years. A similar clock, rubidium-strontium, has a shorter range—from 5 billion to 100 million years ago. Uranium analysis has improved to where it can now date objects a billion years old to an accuracy of 2 pct. Excess ionium found in muds at the bottom of the Atlantic is used to study the sedimentation rate there. Tritium (a hydrogen isotope, weight 3) helps to date air masses, enabling meteorologists to study movement and mixing in the atmosphere.

Incidentally, the belief that the earth crust was 3 billion years old has been revised to 4½ billion years and time span for the pre-Cambrian is now stretched from 2 billion to 3.5 billion years.

M. A. Matzkin

ANNOUNCING



NEW, FASTER-WORKING

NO. 6 SHOVEL

at no increase in price

NEW POWER—the CAT* Diesel Engine now gives you 100 HP, an increase of approximately 25 per cent—and you get it with Caterpillar ruggedness and economy.

NEW 2¼-yd. BUCKET gives you 12½ per cent more capacity, gets heaping loads, dumps cleanly. Exclusive two-position feature gives maximum use of bucket capacity in *any* material: rear position for clean, fast dumping of sticky materials; forward position for carrying heaping loads of loose materials.

GREATER LIFTING POWER and speed with new hydraulic pump: its pressure is stepped up more than 40 per cent for fast, positive lifting action under *all* load conditions.

These extra values cost you no more in price!

These useful attachments increase your job range: skeleton rock bucket, quarry bucket, heavy-duty narrow bucket and bulldozer blade.

Versatile new No. 6 Shovel is built to do more work at less cost

Weight distribution, engine horsepower and bucket capacity are carefully balanced so that the tracks *stay* on the ground for maximum stability.

Your Caterpillar Dealer will be glad to demonstrate the new No. 6 Shovel *on the job.* See him today. And count on him for fast service and genuine factory parts.

Caterpillar Tractor Co., Peoria, Ill., U.S.A.

CATERPILLAR*

*Both Cat and Caterpillar are registered trademarks—®

NAME THE DATE... YOUR DEALER WILL DEMONSTRATE

Drift of Things

IT has recently been impressed on us how few people are aware of the many professional and educational interests and activities in which the AIME is directly or indirectly engaged. The Institute has never gone in for large scale publicity campaigns. It was considered sufficient that we are supporting these various projects—not for public acclaim—but for the genuine desire to advance the profession. Actually, we have been hiding our light behind a bushel, and perhaps it would be well for us to speak up more often. At this time we have singled out just one of the important activities that you should know more about.

AIME is one of five engineering societies that constitute the United Engineering Trustees. UET coordinates the work and efforts of the societies, devoting itself to serve all engineering fields, and represents some 144,000 individual members of the societies involved. One of the divisions of UET, the Engineering Foundation, administered some 20 projects in the fiscal year ending Sept. 30, 1954. Four of these were AIME projects, and the following is a summary taken from the annual report.

Alloys of Iron Research continued its work on the new monograph series. Vol. 1, *Aluminum in Iron & Steel* was published early last year. Vol. 2, a comprehensive summary of data on nickel as an alloying element in steel and cast iron, was published in November. The manuscript for the third volume, *Titanium in Iron & Steel,* was edited for the press. In addition, five chapters dealing with columbium as an alloying element in steel were edited and sent out for review as part of the fourth volume, *Columbium, Tantalum, and Zirconium in Iron & Steel.* The rough draft has been completed for the fifth volume of the series, *Manganese in Iron & Steel.*

Difficulties in solving the complex problems in designing the equipment necessary for securing experimental data on *Heat Flow in Quenching* at Columbia University were overcome early in 1954, and a considerable number of quenching tests have been run. In quenching in still water the cooling rate changes rapidly with small changes in water temperature; if the water temperature rises above a certain value the vapor film on the specimen repeatedly breaks down and is re-formed. These, and other results of this research will undoubtedly prove of value in commercial quenching.

The important fundamental work on *Diffusion in Steel,* which is now in its seventh year at MIT, made substantial progress during the past 12 months. With the discovery, late in 1953, that the rate of diffusion during creep is not the same as in unstressed specimens, a strong emphasis has been placed on this phase of the diffusion problem. Further work along this line should have an important bearing on our theories of the high-temperature strength of metals and alloys.

Comminution Research at MIT completed its third year. During the present year, a method of fine-size analysis was developed by the use of centrifugal elutriation for fractionation. Size distribution was studied with the electron microscope. Work on the kinetic energy of a moving body has been continued; indications have already appeared that a short contact time between impacted and impacting masses should be beneficial in comminution, since a comparatively large amount of kinetic energy can be transferred to strain energy in the impacted material.

In addition, the Engineering Foundation continued its support of several joint society projects, the Engineers Council for Professional Development and the Welding Research Council, and supplied sponsorship and financial support of a project on the Evaluation of Engineering Education. The work of Engineers Council for Professional Development was extensive; the standing committees were active and made commendable progress. In the last year, 24,000 copies of the booklet, *Engineering—A Creative Profession,* were distributed, and a new addition of 75,000 copies is being printed. The other ECPD booklet, *After High School—What?,* has in the past year had a distribution of 40,000 copies. The Education Committee of ECPD has completed its reinspection of U.S. engineering curricula and has been requested to survey professional salaries, laboratory equipment and space, and other details in engineering colleges, to enable deans to compare their facilities with others. The special project for engineering training at the graduate level, started two years ago at Cincinnati with the aid of a special grant from the Foundation, has received excellent local support, and during the last school year, nearly 300 young men have been enrolled in courses at the University of Cincinnati.

Welding Research Council, now in its nineteenth year, supervised through its eight working committees about thirty research and other projects. The amount and quality of the work done by this internationally known group is evidenced continually by the technical papers prepared by its committee members, and its project directors and assistants. Welding Research Council has also extended its field of usefulness to industry during the year by setting up two new advisory committees—on aircraft and on public utilities—to survey, in cooperation with industry, the state of the art of welding in these fields, a survey which could logically lead to a cooperative effort to solve the problems uncovered.

The two year study of engineering education made by a committee of ASEE and 122 institutional committees appointed by the deans of all engineering colleges having accredited curricula, ended with a noteworthy report—presented to the ASEE at its annual meeting. The Committee made one recommendation which if implemented should have far-reaching consequences: that engineering curricula should be divided broadly into engineering-general and engineering-scientific. These two branches should have a common stem consisting of 100 semester hr of mathematics, basic science, engineering science, and humanities, with a little essential technology. The other 38 hr should consist of design, analysis, science, technology, and options or electives.

This is but part of the work of a single division of UET. (*Be Our Guest is the motto of Drift this month. We are most indebted to the manager of publications. —C.M.C.*)

A. S. Cohan

Mining Methods —

Barberton Limestone Mine

by H. F. Haller

COLUMBIA-SOUTHERN'S Barberton limestone mine, 8 miles southwest of Akron, Ohio, is a million-ton-per-year producer from a depth of over 2200 ft in a district where other underground mining at this depth is unknown. Mining extracts 46 of the top 51 ft from a formation of Devonian limestone discovered by drilling in the 1890's. The same drilling revealed extensive salt deposits below the limestone, which led to the location of the chemical plant at Barberton as a division of the Pittsburgh Plate Glass Co. in 1899.

Soda ash was the principal product of the plant, and as production increased the demand for limestone increased. Columbia's first attempt to secure a reliable all-weather source of stone was the development of a quarry at Zanesville, Ohio, in 1919. Zanesville production eliminated some of the stockpiling required by the use of Michigan stone, available only during the lake shipping season. Stone from some Zanesville horizons, however, was found to be more suitable for cement production than for soda ash, and rail transportation remained an important factor. As demand continued to increase, plans were made to develop the Barberton deposit.

Overlying the limestone beds are 2179 ft of Paleozoic sediments and a few feet of glacial till. Shaft sinking was contracted and work was started in 1941 with a crew of miners recruited from outside the district. The 17x8-ft shafts 550 ft apart completed in 1942 were one of the first applications of the Riddell shaft mucker. Connecting between the shafts, excavation for the crusher, storage and loading pockets, and preliminary development continued into 1943.

Beds from which stone is mined are separated by 11 major partings which carry from a trace to 1½ in. of shale. At various horizons within this 46 ft there are 15 horizontal layers of cherty nodules. Bedding is nearly level, and bed thickness is quite uniform. Floor parting dips to the southeast at about 25 ft per mile, and the height of the nominal 46-ft parting above the mine floor varies only 5 to 6 in. in 2000 ft along the dip. Intermediate beds, however, are less uniform. The height of the development back parting varies from 16½ to 19 ft over the floor parting in 3000 ft. The limestone is gray, partly crystalline, and quite hard. Its hardness may be appreciated from its drilling characteristics: an underground type AX diamond drill averages 4.6 in. per min; an automatic feed 3½-in. drifter averages 18½ in. per min for a 6-ft hole.

H. F. HALLER is Technical Assistant to the Mine Superintendent, Barberton Mine, Columbia-Southern Chemical Corp., Barberton, Ohio.

Nearly 300 ft of stone underlying the mine floor is geologically limestone, but only the 51 ft above the floor is chemically kiln stone. The top 5 ft, designated by Stauffer as Delaware limestone, is separated from the lower Columbus formation by a shaly parting which is the back for stoping. Mined formations average about 90 pct $CaCO_3$, the balance consisting of silica, $MgCo_3$, and other carbonates. Since the silica content of the formation immediately below the mine floor is very high, mining this material is avoided. A development height of 15 to 20 ft and a width of 30 to 40 ft were originally planned. The 17-ft parting provided a convenient development back, but early experiments with widths over 20 feet caused the back to loosen and continuous support was required. Roof bolting was tried. When bolt holes were drilled, a small amount of methane gas under high pressure was released and loose backs became solid and required no support. Drilling four 8-ft up holes with every cut was set up as standard practice, and openings are driven up to 36 ft wide without support.

Standard mining is by double entry, room-and-pillar method, although the multiple entry system has been used in some areas. Entries are driven on 65-ft centers, and rooms on 70-ft centers are driven off the right hand entries. Length of the rooms now under development is 1200 ft. Development has progressed to 2100 ft west and 3300 ft north of the hoisting shaft. A stoping area south and east of the shaft has been worked out, and another area extending 2300 ft east is nearing completion. Future plans call for continuing the north and west areas indefinitely, and developing a third area which will extend 2500 ft north and 2800 ft east of the shaft.

Efficient development requires at least eight rooms and two entries in an area. Development faces are broken by 64 to 72 holes depending upon the round. Blasting is confined to the end of the afternoon shift and no production work is done on the third shift, providing a 7-hr period for smoke clearance. Fly rock is bulldozed before loading, and headings are scaled before the cycle begins again. Stoping permits more continuous equipment operation. The remaining 29 ft above the development back is brought down by parallel rows of up-holes drilled at an inclination of 70°. Room backs are drilled to within 20 ft of the entry rib, and blasted at the rate of 40 holes or less to the blast until the entire room has been shot. Loading proceeds until the place is no longer safe to work because the support of loose slabs has been removed. Loading equipment is then moved to another location and the place is made safe. Loading and scaling alternate until the stope has been cleaned.

◀◀◀ **LEFT—Loose rock is removed from the walls and back with a 52-ft pantographic boom mounted on a 19-ton crawler chassis. Loading and scaling alternate until the stope is cleaned of blasted limestone.**

Immediately after the war, small loading and hauling equipment was replaced with larger units to lower costs. LEFT—20 cu yd Tournarocker which replaced end-dump trucks is shown at entry intersection. RIGHT—Haulage units are loaded with 1½-cu yd power shovels. The short boom shovel is designed for low back operation.

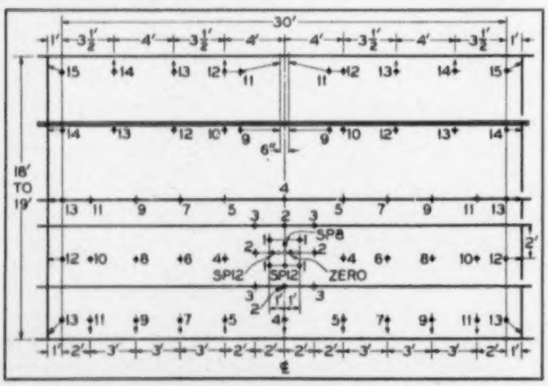
The mine was originally equipped under wartime conditions. As equipment became available, scraper loaders were replaced by 1½-yd power shovels, and lighter loading equipment was modified for use in scaling and cleanup. The 7-ton capacity end-dump trucks were replaced by 20-ton Tournarockers. The original stope scaler, a swinging basket, and a 46-ft boom mounted on a 15-ton crawler-crane chassis, was replaced by scalers with 52-ft pantographic booms mounted on 19-ton chassis. Post, arm, and tripod mountings for development were first replaced by wagon drills and post and arm jumbos, and these have since been replaced by pneumatic boom jumbos on truck chassis. Stopes are drilled from a jumbo mounting 5 or 6-ft change, 3½-in. drifters, which replaced double screw feed machines drilling the same change length.

A department of the Columbia-Southern Chemical Corp., the mine is covered by the plant union contract. Job classifications are many, specific, and rigidly applied to the point where there is no such classification as *miner*. Columbia has no steady source of skilled rock miners. Few such men are available, and the union contract seldom permits direct hiring of drillers, scalers, or blasters as such. A nucleus of experienced men remaining from the shaft contractor's crew has been invaluable in training local labor for mining jobs, but most of these men have developed into foremen or have left the drilling, scaling, and blasting groups. Of the men now classified as drillers, only seven were experienced hardrock miners prior to 1951. Drilling group personnel was reasonably stable in 1950 and blasting produced good results.

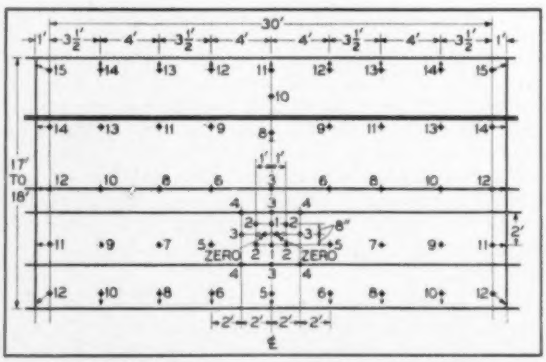
New Jumbo Design

A new jumbo was planned to eliminate defects of the earlier models. Two of these were overloaded 2½-ton truck chassis on which maintenance was high. The crawler mounting of the third was cumbersome and expensive to maintain when used for anything but straight line moving. All three were powered by electric motors, and trailing cables were a constant source of delay. The new rig was designed around a diesel powered 7-ton production truck. Booms 9 ft long minimized machine slide movements. While construction was under way, the 42-in. shells on one of the truck-mounted rigs were replaced by 72-in. shells in an effort to reduce steel changing time. Production from these rigs had dropped to 17 pct below the 1950 average in the first quarter of 1952, and that of the short-feed jumbo remained at this level. The long-feed jumbo, however, averaged 25 pct more drilling than the short-feed rig and continued at 10 pct over the 1950 average into 1953. The new jumbo was provided with 72-in. shells. Although production was about 10 pct better than that of the jumbo replaced, results were not immediately encouraging. Efficiency gradually increased, however, until the 1950 average was reached, and a 10 pct higher average is currently being maintained.

Several variations of the burn cut were tested during this period. The three centerline holes above the 9-ft parting, which could not be drilled by the new jumbo without an additional setup, were replaced by four V-holes. In the 19-ft back, the 64-hole round was being used to break nearly 12 pct more stone than in the 17-ft back for which it was



Elevation of 71-hole burn cut drill pattern which was tried after difficulty was encountered with excessive bootlegs and bad blasts. Efficiency was improved but powder consumption increased.



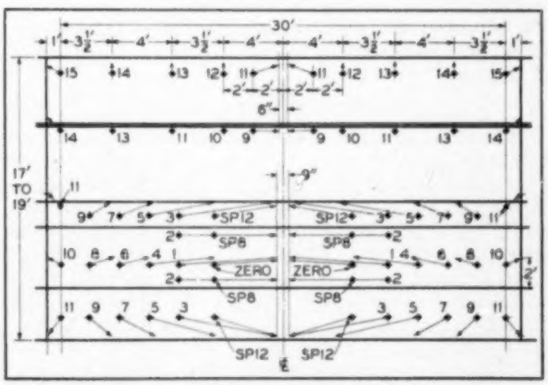
A 64-hole burn cut was standard drilling procedure for several years, but increasing numbers of unskilled miners brought about a drastic reduction in blasting efficiency.

Successful rock breakage is important in underground mining and at Barberton considerable attention is given to this problem. LEFT—Jumbo drilling double V-pattern. CENTER—Closeup of hole aligner used to set up drilling pattern shown in the lower right-hand corner of this page. RIGHT—Five machine stoping jumbo shown drilling out the back of room to complete cycle.

designed. Slight drilling inaccuracies propagated deep bootlegs through the rest of the round. More holes below the 9-ft parting were tried. In one pattern, an additional horizontal row of four holes was drilled on each side of the burn; and in another, an additional vertical line of three holes was drilled on each side. Test rounds of the first pattern averaged only 10 ft per round; those of the second plan averaged 11.1 ft. Since the development back height in most headings was over 18 ft, the second pattern was established as standard for the mine in September 1952. Advances for the year had averaged 10.48 ft. The new round produced an average break of 11.18 ft for the balance of the year.

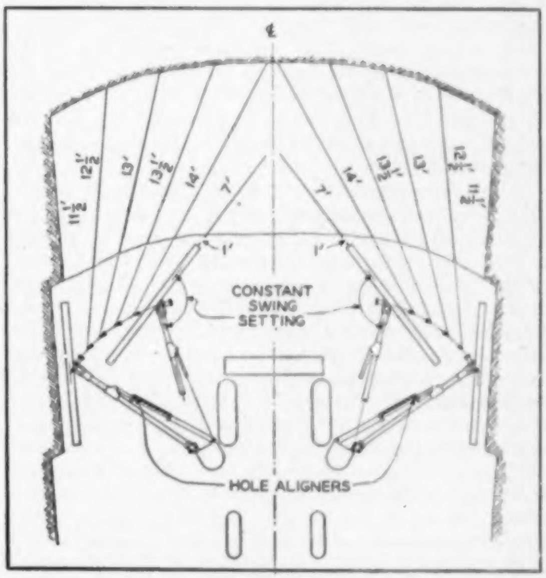
Double V Drilling Pattern

Evaluation of the year's progress showed that while some reduction in manhour costs had been made, the average for the last quarter was nearly 20 pct above the 1950 average. The problem of a more efficient drill pattern recalled previous testing of V-cuts. Although no equipment capable of efficient, accurate drilling was available at the time, tests had shown that such a pattern would break well if properly drilled. The 7-ton truck mounting had proved entirely practical, and investigation of a jumbo to drill V-cuts was begun with this prime mover in mind. After determining what pattern such a rig could be built to drill, two such rounds were drilled, one with and one without a baby cut in addition to a long cut. The double V-cut broke well, and indicated that some saving in powder could be made, but the single V-cut failed completely.



Standard double V-cut recently developed and scheduled to become the standard in headings. Powder consumption was reduced 15 pct from that of the burn cut.

Designed and assembled at the mine, the V-cut jumbo drills a round of 64 holes, 10 of which are 7 ft deep, totaling 753 ft of hole to the maximum 12-ft cut. Hydraulic booms are extendible 33 in., and bottom-deck holes are located by hole aligners clamped to the swing cylinder barrels and lined up with calibrations on the cylinder rods. Horizontal boom alignment without the necessity for freeing and reclamping a swivel head permits drilling a complete row of holes with the same swing and dump settings. Holes above the 9-ft parting are drilled from two jumbo setups, and those below this parting from a third. Top deck machines are 72-in. change screw feeds which drill horizontal holes averaging 12 ft with three steel changes, and gas relief holes from inside the deck. Bottom deck machines have 88-in. change chain feeds, which make it possible to drill all of the bottom holes with two steel changes. Since the unfamiliar power swing feature might be conducive to mishaps, each driller was assigned to one or more shifts of supervised operation. No drilling records were produced, but no accidents occurred. Time and motion studies made during the period are the basis for present standard drilling practices. In the first six months



Plan of the V-cut showing the position of the booms and machines for the four bottom rows of holes. In the first six months, this cut reduced manhour costs by 13 pct.

trial, V-cuts produced average breaks only 4 in. less than the average of burn cuts. Manhour cost was nearly 13 pct less than that of the burn-cut rounds drilled during the same period, and slightly below the 1950 average. Powder consumption has averaged about 15 pct less than that of the 71-hole burn cut. Future plans include construction of two more V-cut jumbos, and eventual elimination of the burn cut.

Drilling with Carbide Bits

Carbide insert bits are being used in all operations. Type I Carset bits have been in use in stope drilling since 1950. Stope holes, drilled at a 70° inclination, are normally 32 ft deep, ending in the shale below the Delaware limestone. Gas-relief rows, at 16-ft intervals, are drilled 6 ft deeper, into the shale above the Delaware. One-in. hexagon stoper steel is used in increments of 6 ft, and 17-ft 4-in. rods are used as extensions. New bits are 1¾-in. diam, and gage loss is normally enough to provide changes after regrinding. Bit life averaged 283 ft in 1950, 642 ft in 1951 and 1952, and the 1953 average for the first eight months was 762 ft.

Original tests of insert bits for face drilling were not encouraging. Further tests in 1952 ran six Type 2 Carsets to destruction. Comparison drilling with steel bits indicated that Carsets could drill competitive footage at greater speed. In an extended test under close control on wagon drills, bit life was nearly twice as great as in the original test. It was decided to change over to Carset bits in all drilling as soon as possible, and to contract bit reconditioning at a commercial shop. In order to control loss and misuse, all Type 2 bits are stamped with serial numbers, and each driller is provided with a bit carrier marked with his clock number. Bit carriers and sharp bits for issue are stored in the dispatch office. When a bit is placed on a driller's carrier the issue is registered. Carriers are issued to individual drillers and are checked in at the end of the shift. As dull bits are removed from carriers, they are checked off in the register. When control of bits was turned over to the tool keepers and mine foremen, insert bits were drilling 30 pct of the development footage. Six months later, 73 pct of this footage was being drilled by Carsets. It was expected that bit life would suffer when bits were placed in general use. This has been true, but the current average footage is still somewhat greater than the low economic limit.

After promising test results, Double Diamond alloy steel was adopted for use in all drilling in 1952. Overall performance has shown an increase in rod life only in proportion to the difference in price. An isolated application which has proved entirely unsatisfactory is the 10-in. section of 1-in. hexagon steel, used in stope drilling to eliminate a long rod change. Spot checks indicated that footage per alloy shank was only one third the average of carbon steel shanks of this length. Over 65 pct of the failures were by thread breakage which normally damaged the coupling as well. A higher percentage of thread failure has also been experienced with the 1¼-in. round alloy rods, occurring usually within ½ in. of the bit skirt. Broken ends are removed by welding to an object which can be held in a vise. There are indications that this operation reduces bit life.

Two periods of millisecond delays are being used in the burn cut, following a Zero delay with an approximate firing time of 50 milliseconds. The first is rated at 240 milliseconds firing time, and the second at 400 milliseconds. These delays were first used to maintain the same delay sequence between the lower rib holes and the back center holes at the time when more holes were added to the burn cut. Better results with this round were apparent, but the effect of the millisecond delays cannot be evaluated accurately. The same millisecond periods are used in the baby cut of the double V-round, following a pair of Zero delays. Either regular or millisecond delays will break well with the same amount of powder, but the throw of fly rock is only about half that experienced with regular delays. Full-scale tests comparing millisecond and regular delays are being carried on.

Rock Crushed Underground

Prior to hoisting, oversize stone is crushed to −7 in. in a 60x48-in. Allis-Chalmers crusher separated from the truck dumping bin by a Ross feeder and a grizzly. The crusher product is conveyed to a vibrating screen, from which undersize drops into the storage pocket and oversize is returned. Two balanced 10-ton skips, loaded through measuring pockets, are hoisted automatically by a 1250-hp Allis-Chalmers hoist. Surface screening separates kiln stone from smaller sizes, and further classifies fines into salable sizes for aggregates and agricultural meal.

Underground maintenance is concentrated as much as possible in a central shop, although a major proportion of repair work and lubrication is done in the field because of the size of the equipment. Because the chemical plant shops are available as service departments for the mine, complete underground maintenance is attempted only on the most unwieldy equipment. Unit assemblies are normally replaced and overhauled outside the mine.

Operating two shifts a day on a seven-day basis requires three complete crews. Various groups work on schedules which rotate in from 3 to 28 weeks, depending upon the number of men involved. Each shift is headed by a mine foreman and three assistant foremen, each of whom is in charge of an operating area. The maintenance supervisor and his assistant normally work on the day shift, as do some other maintenance groups. Shift maintenance crews are supervised by repair foremen and work on the same schedule as the mine foremen. One midnight shift is scheduled each week for maintenance which cannot be done during production shifts. Major overhauls of critical units are scheduled for a shutdown period each year.

Manhours vs Lower Costs

Industrial analysts are stressing the necessity of reducing production costs to meet the competitive conditions of a buyers' market. Some of the recent developments in operating practice described in this paper have been applied on such a small scale that there has been little effect on the cost sheet. Others have been offset by rising labor and material costs so that the net result is a standoff. Under present conditions, money costs of production cannot be reduced without reducing manhour costs to a level well below that of the recent past. Wider application of new developments and continued research will be important factors in retaining a competitive position.

The Search for Australia's Uranium

Main camp at Brown's deposit during exploration and preliminary development of the ore find.

by H. J. Ward

RUM Jungle uranium field lies in the subtropical portion of the Northern Territory on the Finniss River, East Branch. It takes its name from a railway siding about 2½ miles to the southwest and 52 miles from Darwin. The field can be reached from Darwin by a bituminized road.

Monsoonal rains of the wet season, October to April, provide an annual rainfall of about 60 in. Vegetation is of the open forest type with denser tree growth along the watercourses and scattered throughout the area are isolated dense patches of jungle growth which are always found on ironstone cappings overlying limestones. The name, Rum Jungle, is thought to have been derived from this unusual occurrence of jungle growth. The wet season prevents the movement of motor vehicles and personnel. It is not until March, when the grass which ranges up to 15 ft in height is burned and the alluvial flats dry out, that field work can be undertaken.

Following discovery of secondary uranium minerals in September 1949, officers of the Bureau of Mineral Resources inspected and reported on the area. Based on the report, exploratory work was carried out by Bureau officers until provisions were made under Commonwealth Legislation for a mining company to exploit the deposit.

Throughout the investigation the officers of the geological section of the Bureau of Mineral Resources carried out geological mapping, guided exploration, and, for two years, were responsible for the administration of the mining camp.

Geological Setting

Rocks of the area are considered to belong to the Brocks Creek group of Lower Proterozoic age. They are metamorphozed sedimentary rocks consisting of interbedded grits, quartzites, conglomerates, crystalline limestones, and carbonaceous slates, and graphitic schists. Superficial deposits of soil, alluvium, and laterite of Recent to Tertiary age which cover the pre-Cambrian strata in the greater part of the area hinder prospecting and geological mapping.

H. J. WARD, formerly with the Bureau of Mineral Resources, Canberra, Australia, is now with Cerro de Pasco Corp., Cerro de Pasco, Peru.

The sedimentary beds have been folded regionally on axes which strike in a northerly direction. However, in the vicinity of Rum Jungle the sediments have been folded in the form of a dome the core of which consists of granite and granitized sediments.

The most significant geological feature of the area is the Giants Reef Fault which can be traced along its strike for over 50 miles. This northeast-striking fault is marked in many places by quartz reefs standing out above the general level of the surrounding country. Some of the quartz reefs have a cellular structure due to the removal of the breccia fragments which had been cemented together by the quartz. Faults striking in a northwesterly direction have caused minor displacements in Giants Reef fault.

On the southwestern flank of the dome, where the majority of the uranium deposits have been found, the sediments have been displaced horizontally to the northeast on the western side of Giants Reef fault for a distance of 3¼ miles.

Uranium Deposits

Up to the end of 1952 work carried out by the Bureau of Mineral Resources located six uranium deposits within favorable beds of the slate formations and one prospect, the Crater prospect, in a conglomerate bed. The radioactivity at the Crater prospect was considered due to detrital minerals.

Two deposits, the Crater and Mt. Fitch, lie outside the main group of deposits situated in the faulted embayment of sediments northeast of Rum Jungle railway siding. The main group of deposits lie along a line which trends northeasterly from Brown's deposit. They grade from copper rich-uranium poor (Brown's deposit) to uranium rich-copper poor (Dyson's deposit).

White's deposit, the typical copper-rich uranium deposit, was found in an area of sparse, malachite stained outcrops of carbonaceous slates and graphitic schists.

Torbernite was found by a prospector named White in one of two small trenches sunk to test the malachite stained slates in the first decade of this century. Further development work after the discovery in 1949 revealed uranium ochres and tor-

bernite associated with azurite, malachite, cerussite, iron oxides, pseudo-malachite, and dihydrite.

Uraninite was found in carbonaceous slates below the water table which was intersected by shafts at 28 ft below ground level. The uraninite together with chalcopyrite, bornite, and pyrite has selectively replaced the bedding and cleavage of the slate beds. Bleaching of the slates had taken place and it was possible to differentiate high grade ore from low grade ore by the degree of bleaching.

At Dyson's prospect no copper minerals were found associated with the limonite-stained autunite and uranium ochres. The deposit was located in a soil covered area by geophysicists using a Geiger-Mueller counter and then opened up by trenching. The uranium minerals occur in pyritized carbonaceous slates interbedded with quartzites. Diamond drilling and shaft sinking down to 100 ft failed to disclose primary uranium minerals.

History of Geological Work

Within ten days of the discovery of secondary uranium minerals at Rum Jungle geologists of the Bureau of Mineral Resources arrived at the find, early in October 1949.

A preliminary geological and geophysical examination delimited the extent of radioactivity in the vicinity of the find by the end of October. Traverses were made to determine the extent of the Rum Jungle granite and gain an appreciation of the geological setting. On one of the traverses an area of low radioactivity was found about a mile north of Mt. Fitch which is 4½ miles northwest of White's deposit. At the end of the field season a report on the potentialities of the area was submitted.

In March 1950 preparations were made for the field season and all supplies were obtained in Adelaide for the Rum Jungle field party and for three other Bureau of Mineral Resources field parties operating in the Northern Territory.

A party consisting of two geologists, one geophysicist, three field hands, a cook, and a motor mechanic reached Rum Jungle in the middle of May 1950 and a reconnaissance camp was set up on the bank of the Finniss River.

All trenches were mapped tested radiometrically and deepened on the *hot* spots. Shaft sinking on the site of the original discovery at White's was commenced in July 1950 by two contract miners.

Uraninite was found associated with chalcopyrite, bornite, and pyrite within 28 ft of the surface. The presence of pitchblende was confirmed by panning a sample in a prospector's dish.

Radiometric assays of the ore were carried out in the field by comparing equal volumes of samples and standard pulps. The results thus obtained compared favorably with those obtained by more accurate laboratory work.

By the end of July, Brown's, White's, and Mt. Fitch deposits had been mapped in detail and reconnaissance mapping had been commenced on the eastern and southern flanks of the granite. A detailed radiometric survey of Brown's and Mt. Fitch were completed.

In August, a small diamond drill, a Mindrill E100, was obtained to test Mt. Fitch. Costeaning and drilling at Mt. Fitch did not yield encouraging results. The drill was shifted to White's to test the deposit at 100 ft below the surface.

Early in September geophyiscist Dyson, when traversing eastward from White's, discovered the deposit which now bears his name. Trenching in the soil and rubble covered area of graphitic schists and quartzites revealed ironstained crystalline autunite and a shaft was sunk on the best occurrence.

The party ceased field work early in November as the wet season had commenced and facilities for housing men were not available and access to the deposits was difficult to maintain. By the end of the field season 350 ft of shaft sinking, about 1050 ft of trenching and 350 ft of drilling had been completed.

An advance party consisting of diamond drilling team, one cook, one cook's help, two field hands returned to Rum Jungle in March 1951. The camp site was selected and two prefabricated, galvanized iron buildings to serve as a mess and offices were erected before the remainder of the geological and geophysical parties with R. S. Matheson in charge, arrived early in May.

Mining work progressed slowly owing to poor labor conditions. By the end of the year 370 ft of shaft sinking at White's and Dyson's including crosscutting and drifting, 500 ft of trenching and about 2000 ft of diamond drilling were completed.

Two small diamond drills, a Mindrill E100 and a Goldfields No. 7 were available for work at White's, White's Extended, Dyson's and Brown's deposits. Drilling was carried out from April to November.

Regional mapping using air photographs and detailed mapping was continued. Geological plans of all deposits were prepared on a scale of 40 ft to the inch. The margin of the granite within the vicinity of the deposits was mapped.

The geophysical section of the party carried out radiometric assays of samples from mine and diamond drillholes and conducted detailed and reconnaissance radioactive surveys along established base lines. A new deposit, the Crater deposit, was discovered by R. S. Matheson and D. F. Dyson.

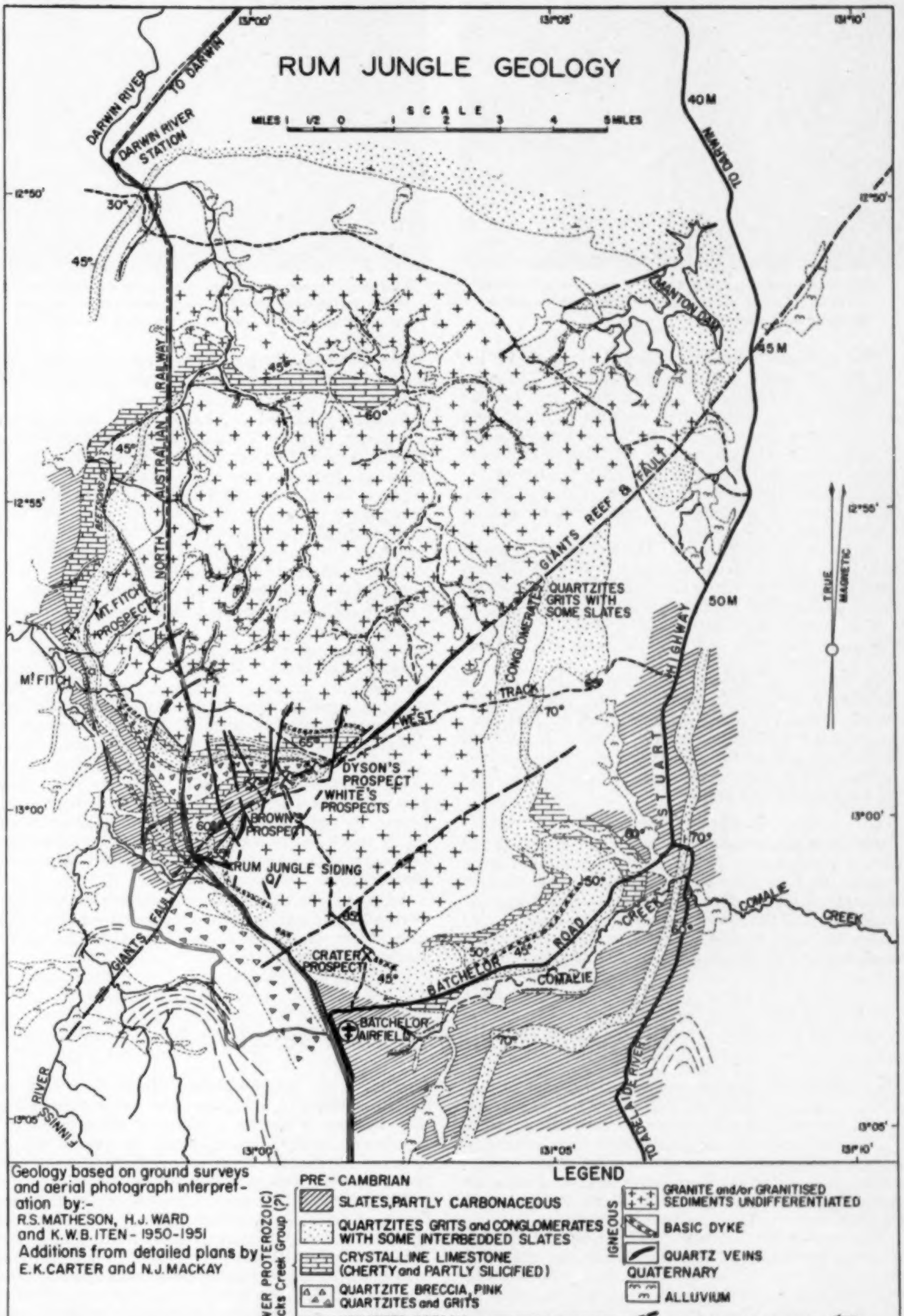
The mining party which reached a maximum of 70 men was reduced to about 50 men when the wet season began in November. Regional geological mapping work was suspended until the 1952 dry season. One geologist and one geophysicist remained behind to guide the mine development. Telephone communication to Darwin had been installed and a road to cope with traffic during the wet season had been made.

During the wet season of 1951 to 1952, primary uranium mineralization was intersected by crosscuts to the southeast of Nos. 1 and 2 shafts at White's deposit on the 100-ft level. Underground diamond drilling with a Sullivan D6 machine had been started from a drift connecting the crosscuts on the 100-ft level. A shaft was sunk at Brown's deposit.

During the 1952 field season the Bureau of Mineral Resources aimed to prove the ore limits at White's deposit by diamond drilling and mining. In the meantime, arrangements were being made by the Commonwealth Government to permit private enterprise develop the prospects.

In April 1952, the author accompanied by two diamond drilling crews returned to Rum Jungle and commenced on a surface diamond drilling program. By June drill crews were operating four surface drills at White's and one underground drill. Drillers were trained on the spot and worked 12-hr shifts. More than 9000 ft of drilling was completed by November.

During the year, drifts were made on the hanging and footwalls of the lode and crosscuts tested uranium mineralization found by diamond drilling.


RUM JUNGLE GEOLOGY
SCALE
MILES 1 1/2 0 1 2 3 4 5 MILES
DARWIN RIVER
TO DARWIN
DARWIN RIVER STATION
40M
45M
50M
TO DARWIN
MANTON DAM
NORTH AUSTRALIAN RAILWAY
GIANTS REEF & FAULT
QUARTZITES GRITS WITH SOME SLATES
CONGLOMERATES
MT. FITCH PROSPECT
Mt FITCH
WEST TRACK
STUART HIGHWAY
DYSON'S PROSPECT
WHITE'S PROSPECTS
BROWN'S PROSPECT
RUM JUNGLE SIDING
CRATER PROSPECT
BATCHELOR ROAD
COMALIE CREEK
COMALIE
BATCHELOR AIRFIELD
GIANTS FAULT
FINNISS RIVER
TO ADELAIDE RIVER
TRUE
MAGNETIC
Geology based on ground surveys and aerial photograph interpretation by:-
R.S. MATHESON, H.J. WARD and K.W.B. ITEN - 1950-1951
Additions from detailed plans by E.K. CARTER and N.J. MACKAY
FROM BUREAU MINERAL RESOURCES, GEOLOGY & GEOPHYSICS MAP NT 47E-4 JUNE 1952.
LEGEND
PRE-CAMBRIAN
(LOWER PROTEROZOIC) Brocks Creek Group (?)
SLATES, PARTLY CARBONACEOUS
QUARTZITES GRITS and CONGLOMERATES WITH SOME INTERBEDDED SLATES
CRYSTALLINE LIMESTONE (CHERTY and PARTLY SILICIFIED)
QUARTZITE BRECCIA, PINK QUARTZITES and GRITS
HEMATISED BRECCIA-CONGLOMERATE.
IGNEOUS
GRANITE and/or GRANITISED SEDIMENTS UNDIFFERENTIATED
BASIC DYKE
QUARTZ VEINS
QUATERNARY
ALLUVIUM
GEOLOGICAL BOUNDARIES
FAULTS DEFINITE
FAULTS APPROXIMATE
STRIKE AND DIP OF BEDDING
URANIUM PROSPECTS
STRUCTURE LINES

Life in exploration camps of Northern Australia lacks some of the most deluxe accommodations, but lunch hour finds the whole crew present.

Bulldozers proved to be the work horses of the Rum Jungle camp for clearing, trenching, and construction. A good prospect trench is valuable to the geologist.

The geological section continued to supervise the mining, trenching, and diamond drilling. The sampling and surveying of underground and surface workings and diamond drillholes were undertaken by geologists. Diamond drillholes were geologically logged and a geologist was in attendance at all ore intersections at White's deposit. Geophysicists radiometrically assayed all samples, radiometrically logged diamond drillholes and kept a close check on underground working faces.

To house the workers over the wet season a mess-hut, huts, and bathrooms, prefabricated in Darwin were erected near White's deposit. The construction of a sealed surface road was begun.

Staff houses were erected at a townsite, selected earlier in the year, at Batchelor Airfield 6½ miles to the south of the mine workings.

In November Territory Enterprises Pty. Ltd., a subsidiary of Zinc Corporation Pty. Ltd. of Melbourne, agreed to take over operations as from January 1953. Consequently the Bureau of Mineral Resources geologists, geophysicists, and diamond drilling teams were withdrawn from the Rum Jungle area at the end of 1952.

Geophysical Methods

Airborne scintillometer surveys had disclosed radioactive anomalies outside the Rum Jungle area. During the 1953 field season the Bureau of Mineral Resources conducted geological and geophysical investigations of the most promising of the radioactive anomalies, and, if necessary, followed up the investigations by trenching and diamond drilling.

Self-potential, ground and aerial radiometric, and magnetometer surveys were carried out in the Rum Jungle area.

Surface radiometric examinations were carried out using portable Geiger-Mueller counters—type PRM 100 made in Australia, and type 1000, made in England. Extreme care was taken to avoid the mechanical and electrical defects likely to be caused by excessive humidity. The base lines and grids used in geological mapping were the bases of all geophysical work around the deposits. The results of surface radiometric examinations were used in planning diamond drilling in soil covered areas.

The geophysical section of the Bureau of Mineral Resources designed special equipment for the radiometric logging of diamond drills of EX size and greater. The holes were logged as soon as drilling was finished, whether it was day or night. Until suitable assaying equipment was obtained the type 1011 ratemeter was used to compare readings of samples with those obtained from standard pulps.

All mine, drillhole core, and drillhole sludge, samples were radiometrically assayed. Mine samples were crushed in a mortar with pestle until power driven crushing equipment was obtained. Assay results were made available to the geological section within 8 hr and in special cases in a much shorter time.

Airborne scintillometer and magnetometer surveys which discovered new radioactive anomalies were made from the Royal Australian Air Force station at Darwin.

Diamond Drilling at Rum Jungle

DIAMOND drilling was increasingly used to test the uranium deposits and in 1952 four surface drills and two underground drills were in operation.

Diamond drill bits and spare parts were generally sent by air freight from Melbourne. Such equipment as diamond drill rods, casing, and heavier equipment was sent by rail to Alice Springs and then by road transport to Rum Jungle.

The two-man diamond drilling team which arrived in 1950 formed the nucleus of the diamond drilling section. These two men with two to three years experience in drilling trained selected men to become drillers. The men chosen for training were first given jobs as sludge samplers. They were encouraged to help the drillers and become generally familiar with the machines. When they had acquired sufficient knowledge they were promoted to drill helper. With the addition of three more experienced drillers it was possible to operate the six diamond drills for two 12-hr shifts during the greater part of 1952.

The geologist in charge of mine exploration and diamond drilling was responsible for the supply of equipment, the selection of men for training, and the layout of drill sites.

Electric light and water lines were laid to drill sites at White's, White's South, White's Extended, Dyson's and Brown's deposits. For the isolated prospects such at Mt. Fitch and the Crater, water was carted in truck-mounted 800-gal tanks. A ½-hp

Prefabricated huts were erected to house the staff during the exploration and development of the uranium find. The location shown above is near White's deposit.

portable water pump was used to fill the tanks from the nearest waterhole.

Types of Drills Used

The diamond drills used on the project were:

a) Screwfeed: Mindrill E100, range 100 ft with EX rods
Goldfields No. 7, range 300 ft with EX rods
Mindrill A3000, range 1100 ft with AX rods

b) Hydraulic feed: Sullivan HD22, range 1100 ft with AX rods

c) Air driven screwfeed: Sullivan D6 and Mindrill XR350, both used for underground work.

Core Recovery

Core recovery was poor, averaging about 29 pct during the three years of drilling. The low core recovery can be attributed to the nature of the rock formation and the size of the holes.

About 90 pct of the drilling was in a slate formation consisting of carbonaceous slates, graphitic schist, and chloritic schists. Of these rock types chloritic schists cored the best and the graphitic schists the worst.

Crystalline limestone and quartzite breccia cored well in the unoxidized zone. Lateritized limestone did not give satisfactory results and in the Mt. Fitch area did not core at all.

The Mindrill E100 and Goldfields No. 7 drilled holes less than 200 ft in length with EX equipment. In some holes greater than 100 ft XR equipment was used in the Mindrill E100. The core recovery was greatest in AX holes when using a nonrotating inner tube core barrel with the hydraulic feed drill.

The average speed of drilling was 1.5 ft per hr. Rates of 5 ft per hr were obtained with the larger drills whereas the light drills attained a maximum progress of 3 ft per hr.

Sludge Sampling

Sludge samples were taken from all holes drilled. The sludge was run from the collar of the hole through a launder to a sludge splitter. The sludge splitter, which was designed and made locally, quartered the sludge, and the sludge to be saved flowed into a series of containers. The containers were made from 44-gal petrol drums which had been cut lengthwise. Three half drums collected the sludge from a 5-ft run. The sludge when collected was allowed to settle, the water siphoned off, and then dried out slowly over a fire at the drill site. After drying, the sludge was put into a canvas sample bag with a numbered label. Details of the location of the sample, that is drillhole number and footage, were marked on the label book. At the end of each shift, samples were despatched to the geophysical laboratory for radiometric assay.

Extreme care had to be taken to prevent the escape of light flaky secondary minerals which did not settle readily in decanting the water from the sludge before drying. To prevent loss, a fine meshed gauze was tied to the bottom of the siphoning hose and any sludge collected thereon was scraped off and saved.

The collection of sludge samples from underground necessitated extreme care. The containers were fitted with lids to prevent loss by splashing when being transported to the surface for drying. Core was stored both in boxes and in racks with corrugated galvanized iron shelves.

Surveying Drillholes

A Tropari borehole instrument was used to survey the bearing and inclination of all holes exceeding 200 ft in length. The variation in dip was generally 1° per 100 ft in holes whose inclination lay between 45 and 60°.

A radiometric survey of each drillhole of EX size and greater was made as soon as the hole was completed. The graph of radioactivity thus obtained was compared with the sludge and core assays and geologic logs. With practice it was possible to correlate changes in radioactivity with rock type.

Hammer drillholes were driven into the sides of hanging wall and footwall drifts to determine the presence of disseminated uranium ore. The cuttings from the drillholes were collected in numbered tins, taken to the surface, dried, and despatched for assay.

At first, trenches were cut by pick and shovel. This method was improved upon by drilling and blasting the ground and then removing the broken rock with a ¼-cu yd scoop drawn by a jeep. Bulldozers were later used for trenching.

In the Mt. Fitch area, in 1950, posthole diggers were used to penetrate soil and decomposed lateritized limestone. A 6-in. diam posthole digger with 14 ft of extensible rods was used to locate rock boundaries. Radiometric anomalies were quickly tested by lowering the Geiger-Mueller tube into the posthole.

Camp Administration

In the early stages of the project, camp administration was the responsibility of the geologist in charge. The principal problems were the maintaining of regular food supplies for an increasing number of men, provision of sufficient water for domestic purposes, the hygiene of the camp, the maintenance of motor vehicles, camping equipment, and means of access to the area. It was necessary to be fully conversant with the regulations and Arbitration Court awards pertaining to the unions whose members were working on the field. The geologists organized the camp sporting and social activities.

References

H. J. Ward: Report on the Occurrence of Radioactive Minerals in the Vicinity of Rum Jungle Railway Siding, Northern Territory. *Comm. Bur. Min. Res. Geol. & Geophys.* Unpublished Report (1949).

L. C. Noades: A Geological Reconnaissance of the Katherine-Darwin Region, Northern Territory. *Comm. Bur. Min. Res. Geol. & Geophys. Bull.* 16. 1949.

C. J. Sullivan and R. S. Matheson: Uranium-copper deposits, Rum Jungle Australia. *Econ. Geol.* vol. 47, No. 7, pp. 751-758.

Rum Jungle, Mining Engineering, Vol. 6, No. 5, May 1953, p. 486.

Rotary Drilling Fluids in Exploration Drilling

The drilling fluid system is the heart of the rotary oil drill—any other type rotary rig can benefit by adopting drilling muds.

by W. D. Lacabanne

DRILLING fluids as an aid in drilling holes into the earth have been in use successfully for more than a half a century. Originally used in a primitive fashion in water well drilling before the turn of the century, drilling fluids came into their own in 1901 when they were incorporated as an indispensable part of the newly invented rotary oil drilling method. Since drilling fluids have been the basic factor in successful modern oil well drilling, attested by the dramatic growth of the U. S. petroleum industry, their study and development have naturally taken place in the oil industry. An abundance of engineering and scientific literature has appeared on the subject of drilling fluids.

Application to Exploration Drilling

The drilling fluid system is understandably called the *heart* of the rotary oil drilling rig. Any other type of rotary rig, such as the diamond drill, should benefit by the incorporation of mud fluids in the drilling scheme.

Drilling fluids may consist of clear water only, of water and clay materials in the form of a mud, thick or thin depending on the amount of clay, or a more complicated suspension in water containing finely divided materials and chemicals. The fluid is circulated by powerful pumps through the drill rods to the bit where the mud fluid emerges and returns to the surface through the annular space between the rods and the walls of the hole. A settling ditch or a vibrating screen is used to remove sand particles and drill cuttings, and the cleaned mud finally flows to the storage tank for recirculation.

Composition of Drilling Mud

Water base rotary drilling fluid is made up of three principal parts, the liquid phase, the soluble phase, and the suspended phase. The liquid phase is water; soluble phase is chemical; and the suspended phase is particles both chemically inactive and active. Soluble chemicals commonly found in clays are the chlorides and sulphates of sodium, calcium, and magnesium. The inert coarse fraction of the suspended phase consists of particles of clays, silts, sand, and cuttings that have diameters between one half micron and ¼-in. or larger, while the active colloidal fraction is fine particles of bentonite and mud clays that have diameters between one thousandth of a micron and one half micron. The water provides the suspension vehicle for all particles and the solution medium for solubles. The inert particles supply the specific gravity and the chemically active colloids affect the viscosity and gelation of the mud. The colloids or gel fraction of the mud fluid, though present only in small amounts, greatly affect the properties and behavior of the mud since the colloids are sensitive and are easily damaged by small quantities of salt or certain chemicals. But they can be improved by further additions of bentonite and clays. Colloidal particles can be chemically flocculated to produce thickening, or can be chemically dispersed to produce thinning of the mud. Thus, the major part of mud control is directed to the colloidal fraction.

W. D. LACABANNE is Assistant Professor, Petroleum Engineering, University of Minnesota, Minneapolis.

Terminology

BENTONITE—Highly plastic, highly colloidal clay is largely made up of the mineral montmorillonite.

BARITE—High density compound, the mineral barium sulphate, which when finely ground has a specific gravity of about 4.3.

FILTRATION LOSS—The quantity of water lost from a mud to a porous rock and is measured in cubic centimeters in a low pressure filter press.

MUD CAKE—The semihard layer of mud solids remaining on a drill hole wall when the mud loses liquid to the formation.

GEL—A colloidal suspension which when at rest sets into a plastic or semisolid state having shear or gel strength.

THIXOTROPY—The property possessed by certain gels of repeatedly becoming fluid on agitation and again gelling when at rest.

MUD WEIGHT—The density of mud fluid expressed in various units (lb per gal).

Water base drilling fluids do not possess properties that will endanger operating personnel. The mud is not toxic to the skin nor damaging to clothes and is easily washed off.

Properties of Mud Fluids

Properties of rotary drilling fluids may be divided into two parts, the functional and the operational. The most important functional properties are the viscosity, gel strength, and density. All three properties vitally affect the carrying power or the ability of the mud to transport cuttings from the hole.

The principal operational properties of the mud fluid center on its filtration characteristics. Filtration loss, or water loss to the formation should be low and a low filtration loss usually gives a thin, impermeable filter cake which protects swellable formations. The particles in the mud, their shape, size distribution, concentration, and degree of dispersion, affect the plugging or sealing ability of the mud cake. Coarse particles of poor size distribution build thick, porous cakes, while fine to colloidal size

Functions of Drilling Fluids

A drilling fluid must perform a large number of complex functions simultaneously, a large requirement for any single system.

1. **Removal of Cuttings from the Hole**—Rock cuttings produced by the action of the bit are removed from the bottom of the hole to the surface by the circulating drilling fluid without interrupting the progress of drilling. Removal of cuttings and *making hole* go on simultaneously.

Particle size, differences in specific gravity between the particles and mud, high viscosity and gelling behavior of the mud create conditions of low settling rates for particles while moving up the hole, but these same conditions at the surface prevent the cuttings and sand particles from settling out of the mud. Thin-streaming the mud fluid over a wide area to reduce the distance of particle drop may help, particularly if the gelling is not too great, but use of vibrating screens is the most effective method of removing cuttings from a drilling fluid. The drilling fluid laden with cuttings is passed over the vibrating screen, and cuttings larger than the screen openings remain on the screen, while the clean mud passes through and is recirculated.

2. **Cooling the Bit and Drill Rods**—The circulating mud fluid cools the bit and drill rod which become heated from cutting action and friction of rotation in the hole. The drill hole is a confined space and acts as a thermal insulator, thus, the frictional heat developed by mechanical action of the tools builds up high temperatures unless removed by circulating fluid.

3. **Lubrication of Bit and Drill Rods**—The lubrication of mechanical parts in rubbing contact reduces the friction between them and in the same manner, lubrication of the drill bit and rotating rods by circulating mud fluid reduces the friction between them and the rock. Power required for rotation of the tools and wear on the rotating rods is reduced. Also, the slick film on the walls of the hole permits easier pulling of rods. Good lubricating properties can be imparted by small quantities of bentonite.

4. **Prevention of Wall Caving**—Unsupported, weak drill hole walls tend to break off and fall or cave into the hole. Some formations wetted by drilling water may slough off into the hole or swell and diminish the hole diameter. Presence of a column of mud fluid in the drill hole with its hydrostatic head exerts a force against the walls and helps to support weak walls. Wall supporting action of the mud fluid may be augmented by an increase in mud specific gravity to raise the hydrostatic head.

5. **Wall Plastering Action and Mud Cake Formation**—In the drill hole, mud fluids under the condition of excess hydrostatic head over formation pressure will plaster the hole walls with a thin to thick, soft to hard, layer or sheath, which is commonly called mud cake, filter cake, or simply cake. Plastering action is assisted by the rotating drill rods. The existence of a mud cake in the drill hole may have far reaching effects on the success or failure of drilling.

Thin, tough, impermeable mud cake is desired as it does not interfere with the tools, maintains low filtration loss, low formation swelling, gives good plastering characteristics, and helps prevent caving.

Proper mud control will keep wall cakes thin and impervious and hold filtration loss to swellable formations down. Good wall mud cake is effective in sealing off formation waters from the hole when the mud column head is less than the formation pressure. Bentonite is an excellent material to improve the wall building characteristics of a mud fluid.

6. **Preventing Water Influx**—Water under pressure is often encountered when drilling through porous formations, but such water may be controlled by a column of mud fluid of the proper weight. The mud column hydrostatic head may be made greater than the formation water pressure by increasing the quantity of clay solids in the drilling fluid. Simple water-clay muds may have densities as high is 75 lb per cu ft, high enough to control water in shallow holes.

7. **Mud Fluid Jetting Action**—Under high pump pressure, a mud fluid at the bottom of the rod string emerges from the bit openings at high velocity and impinges on the formation rock ahead of the bit cutting edges. The jetting action assists the bit in cutting rock and in cases where the rock is not too flintlike the drilling rate is increased in proportion to the mud circulation. In soft formations the jetting action does more digging than the bit.

8. **Casing Reduction**—A good mud properly controlled in the hole may reduce the amount of casing required to protect and maintain the drill hole. Sufficient hydrostatic head, good plastering properties, and low water loss to formation may hold up the walls, maintain full diameter, and control loss of mud to the formations and prevent influx of water from the formations. Thus, a drill hole may be kept in workable condition without casing which otherwise would require casing if mud were not used.

9. **Securing Accurate Hole Information**—The primary purpose of the diamond drill hole is to secure accurate subsurface mineralogical and geological information, usually in the form of drill cores or cuttings. The characteristics and properties of the drilling mud must be such that good cores and cuttings, representative of the formations, and perhaps good electric logs, will be obtained.

10. **Prevention of Drill Rod Corrosion Fatigue Failures**—Corrosion fatigue failures occur in drill rods that are excessively stressed in operation while immersed in a corrosive drilling fluid. The development of incipient cracks in and the formation of deep pits on the inside surface of the rods, particularly at the joints and threaded sections, is accelerated by a corrosive mud. Some contaminants encountered in drilling, such as salt and hydrogen sulphide, are especially corrosive.

particles of good size distribution build thin, tough, impermeable mud cakes.

Sand content of more than 2 to 3 pct of particles larger than 200 mesh makes the mud fluid abrasive, and material of this type should be kept at a minimum to reduce rod and tool wear.

Viscosity and Weight Characteristics of Mud Fluids

When solids are added to water and the dissolved salts are not considered, the viscosity, density, and gelation of the mud vary with the percentage of solids present. Also, the character of the added solids is an important factor. Briefly, the general features of the variations are as follows:

a) Solids of high colloidal content and low inert particle content added to water in small percentages increase mud viscosity with little change in density. The addition of about 8 pct by weight of bentonite to water at room temperature changes the mud viscosity from about 1 to about 60 centipoises while the density changes from 8.4 to about 8.7 lb per gal. This mud has good to excellent gelation properties.

b) Solids of high inert content and low colloidal content added to water increase mud density with little change in viscosity until a critical amount is reached. At this point the viscosity increases suddenly. The addition of poor mud-yielding clays up to 42 pct by weight changes the mud density from 8.4 to about 10.9 lb per gal while the mud viscosity increases slightly from 1 to about 8 centipoises. An increase in percentage of solids above the critical point (42 pct) to 50 pct, increases the mud density slightly from 10.9 to about 11.6 lb per gal but the viscosity increases abruptly from 8 to 60 centipoises. The gelation properties of this type of mud are generally poor.

Properties of Native Clays for Mud-Making

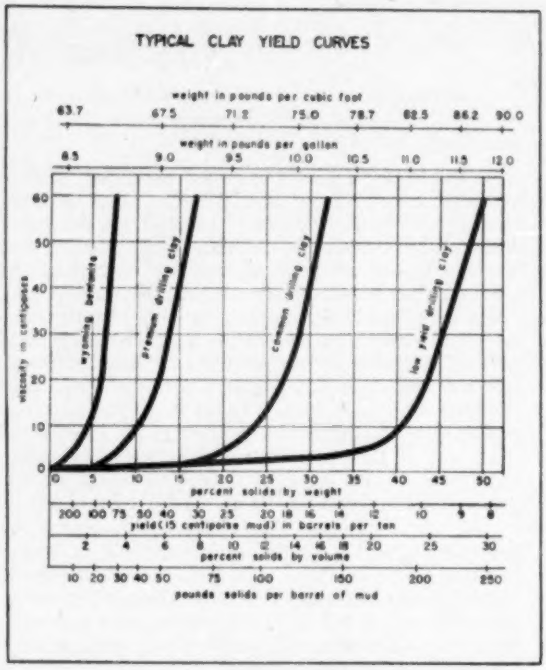
Mud-making properties of a clay are characterized by the yield of usable mud fluid. The yield is defined as the number of barrels of mud of 15 centipoise viscosity per ton of dry clay. Highly colloidal materials give a yield of up to 90 bbl of usable mud fluid per ton while yield of poor clays is as low as 10 bbl. Native clays generally have a low content of hydratable colloids and contain considerable sand and other noncolloidal inert material. Native clays generally are low yield materials and the best may yield only 50 bbl of mud per ton. Clays for use in drilling fluids must be carefully selected.

Mud yields from bentonites and clays depend on the use of good, soft water. Hard, mineralized waters reduce mud yields and give poor performance. Waters containing more than 5 pct salt cause bentonites and clays to lose their gel and viscosity-making properties.

Mud Control

Normal shallow drilling generally requires only simple mud control such as water dilution of mud with perhaps small additions of bentonite, clay, weighting materials, and chemical thinners.

The viscosity and density of a mud may increase during drilling because of pulverized material from the hole. If water dilution of the mud will lower both the viscosity and density back to operating values, the mud may be maintained in proper condition by the use of water alone. But, if the water dilution reduces the mud density sufficiently but the viscosity is below operating values, small quantities of bentonite are added to return viscosity to proper values. Thus, the mud may be maintained with water and bentonite only. However, if the reverse



The author points out that native clays are generally low yield materials in terms of usable clay per ton of raw material, while the best may produce only 50 bbl per ton.

occurs, the mud viscosity may be reduced with a chemical thinner with slight effect on the density. An alternate procedure for this same mud condition is excessive dilution of the mud with water to reduce the viscosity which reduces the mud density below the desired values. The density may be brought back to operating values by the addition of heavy weighting materials. In practice water dilutions in slight excess are needed to counteract the treating materials added to the mud.

Control of Formation Waters

The drill bit frequently encounters formations containing waters which enter the hole and cause difficulties in drilling. Proper weight control of the drilling fluid often controls the invading waters.

The fluid pressure gradient for fresh water is 0.433 psi per ft of depth (or 43.3 psi per 100 ft of depth) and for sandy and porous formations of 500 to 1000 ft depth the ground water pressure gradient is probably close to the 0.433 psi per ft value. When water is used as the drilling fluid the hydrostatic gradient in the drill hole is also 0.433 psi per ft of depth and the hydrostatic head produced would counterbalance the hydrostatic head of the formation water. But during the course of drilling, drill cuttings, clay, and other fine particle material are picked up and the drilling water becomes loaded to form a mud fluid and consequently makes a mud column of greater hydrostatic head than the formation water pressures at any given depth. The drill hole should be kept full, so that the circulating fluid can be kept under pressure, thereby assisting the control of invading formation water.

Loss of Drilling Fluid to the Formations

Lost circulation, or the loss of mud fluids to porous or fissured formations, is frequently encountered in drilling, and certain methods to combat lost

circulation have developed. The more effective methods are:

1) Reduce mud weight and/or pump pressure
2) Increase mud viscosity and gel strength
3) Use of sealing agents
4) Cement—for extreme conditions

In a 500-ft hole filled with a 70 lb per cu ft mud the previous example has shown that a 26.5 lb differential may exist between the hydrostatic head of the drilling fluid and the normal formation pressure. While this hole-favored differential will prevent formation waters from flowing into the drill hole the reverse may take place and the pressure differential may be the cause of loss of mud fluid to the formation. Sands and gravelly formations and cracks having openings of 0.1 millimeter to 1 millimeter can cause loss of mud returns.

Mud Fluids and Drilling Operations

When pulling drill rods the mud level in the hole is lowered and as a consequence, the hydrostatic head is reduced. If the mud column is critically balanced to control formation pressures and to support the walls of the hole the lowering of the mud level is critical. To counteract possible trouble, the hole should be kept full while rods are being pulled.

When running into a hole filled with mud in critical hydrostatic balance, pressure surges created in the mud column may break down formation pressures. A pressure surge acts like a hydraulic ram when rods are pushed down into a viscous mud.

Mud Records

A few words should be given on the subject of recording mud data obtained from mud tests and from general observations of mud behavior under operating conditions. Mud records for a drill hole assist in evaluating and improving the mud program which may help to lower the drilling mud costs. Mud records also are valuable where the experience at one hole may be applied to another in the same geological vicinity. Supply companies willingly furnish printed record forms for recording mud data.

Much detail has been omitted, but numerous publications are available describing drilling fluid techniques and testing methods. The accompanying bibliography will be of assistance to those wishing to pursue the subject further.

Bibliography

Composition and Properties of Oil Well Drilling Fluids. Gulf Publ. Co., 525 pp., 1948

Principles of Drilling Mud Control, 9th ed., 122 pp. Petroleum Extension Service, Univ. of Texas, Austin, 1952

Recommended Practice for Standard Field Procedure for Testing Drilling Fluids, 3rd ed., RP 29. American Petroleum Institute, Dallas

Drilling Mud, September 1950, November 1952. Baroid Sales Div., National Lead Co., Los Angeles

Field Testing of Drilling Mud

The testing of drilling fluids in the field is now routine and standardized tests have become established. The American Petroleum Institute has set up recommended standard field procedures for testing drilling fluids and the outline and details of these tests can be found not only in the API standards, but in the supply company literature.

One group of field tests measures density, viscosity, gel-strength, filtration, sand content, and tests the physical properties of the mud fluid. The other set checks salt concentration, water hardness, pH, and the chemical properties.

Density Test—Density or mud weight may be measured by a balance or a hydrometer. Both are simple in construction and simple to use, for only a cupful of mud fluid is required to fill the instrument.

Viscosity Test—Viscosity of mud fluid may be measured either by the simple Marsh funnel method or the more precise, laboratory type, Stormer viscosimeter method. The common test is to place 1500 cc of mud in the funnel—the level of this volume just reaches a built-in screen—and to time the efflux of 1 qt of mud.

Gel Strength Test—Gel strength of muds is usually measured with the Stormer viscosimeter by attaching driving weights to the spindle until the spindle revolves a fraction of a turn. The initial gel strength is measured as soon as the mud is no longer agitated in the cup, and the magnitude of the driving weights in grams to cause ⅛ revolution of the spindle is the initial gel strength.

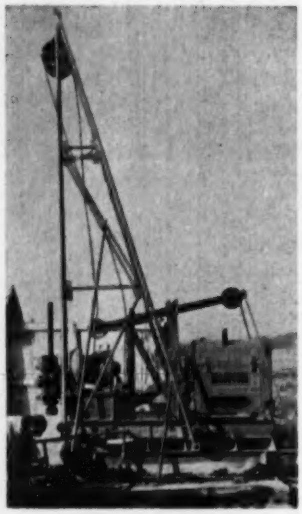
Filtration Test—The filtration or wall-building characteristic of the mud is measured in a filter press operated at 100 psi. A pint or less of mud is placed in a strong-walled cup or cell equipped with a screen and filter paper on the inside bottom, capped with a cover, and placed in a strong frame to hold the assemblage together when under pressure. Compressed air or bottled nitrogen regulated to 100 psi is connected to the top of the cell and held for 30 min. The squeezed-out filtrate is caught in a graduated cylinder and is read in cubic centimeters as fluid loss. When the cell is disassembled the mud cake thickness is measured in 1/32 in.

Sand Content—The sand content of a mud may be determined directly in percent through the use of a convenient sieve-funnel-calibrated glass tube arrangement. The correct amount of mud—about 50 cc—is measured into the glass tube, diluted with water and shaken, and poured onto the screen. By a series of water dilutions, shakings, and transfers from tube to screen, repeated until the wash water is clear, the abrasive sand grains are isolated and finally caught in the graduated tube from which the percentage of sand in the mud is read directly.

Salt Content—The amount of salt in a mud is determined by the total chloride ion concentration in the mud filtrate. By means of a titration test on a small quantity of filtrate the total chlorides in the filtrate is reported in parts per million. Sea water contains about 35,000 ppm and the chlorides in a mud fluid should be less than 5000 ppm.

pH Test—The pH or hydrogen ion concentration in a mud may be measured quickly and easily with colored paper test strips. Precise values of pH may be measured by an electrometric method. The pH values of water-clay muds are around 8.

Water Hardness—The test for hardness of water, i.e., presence of calcium ion, is simple requiring only a standard soap solution, distilled water, graduated pipette tube, and bottle for shaking the water and soap mixture. When a permanent foam develops after sufficient addition of soap solution to the water sample and after vigorous shaking, the number of cubic centimeters of soap solution used is divided by the cubic centimeters of water sample. Hardness value is this ratio, multiplied by a constant. ● ● ●



Type of diamond drill used by Dragon Cement Co. for exploration.

Diamond Core vs Churn Drilling In Exploration

by Frank J. Anderson

IN the cement region of the Lehigh Valley, a difference of 2 to 3 pct in $CaCO_3$ can make or break a new quarry development, and experience of the Dragon Cement Co. has shown that values of calcium carbonate, as reported from churn drill samples, have been increased as much as 6 pct on the average when the same area was diamond drilled. This calcium carbonate increase consequently lowered the values for silica, iron, and alumina, and made these sections much more attractive.

Since 1950, the Dragon Cement Co. Inc. has been engaged in extensive diamond drilling in the local limestone of the Northampton, Pa., region, known as the Jacksonburg formation, and in the Lebanon, Pa., region in the Annville limestone, both of Ordovician age.

In 1926, an extensive churn drilling program was carried out by the Lawrence Portland Cement Co., now the Dragon Cement Co. Inc., at both Northampton and Lebanon, and results of these drillings governed part of the operation and policies of the company for many years.

In 1950, an accurate compilation of all churn drill data available since 1926 was begun in an attempt to evaluate the company's overall holdings and select the most promising areas of usable limestone. Much difficulty was encountered, especially in the Northampton region, when subsurface sections were drawn, for it was impossible to correlate one churn drill hole with another drilled 50 ft away. Naturally, there are many reasons why two adjacent drill holes in the same formation cannot be correlated, but upon further investigation it was found that correlation was impossible within a pattern of drill holes on 100-ft centers. Answers to this problem were sought from other local cement plants that had engaged in churn drilling exploration programs, and it was generally found that the same type of problem existed.

It may be well to bring out three important points regarding past exploration in the local cement area. One is that churn drilling was done, not to provide geologic correlation, but to provide indications of the chemical content of the stone that would some day be quarried. Some diamond drilling was done, but the cost and general operation at that time were not considered satisfactory.

Prior to the late 1930's geologists were practically unheard of in cement plant operations, and the work of interpreting churn drill samples was left to men who were better trained in other fields and had no working knowledge of geology. At times consulting geologists were brought in to supervise and interpret drilling data, but for the most part the work done was not satisfactory.

As of 20 years ago, most cement plants had no problem as far as reserves of raw material were concerned, however, within the last few years, reserves have become low in many localities and intensified exploration, under the guidance of trained geologists and geological engineers, has been undertaken. As a result the picture has changed greatly.

Diamond Drilling

The type of drilling rig used in company exploration is shown in the photo. The overburden, ranging to 50 feet in thickness is penetrated with an NX size diamond bit attached to a 2-ft core barrel. This same bit cores approximately 1 ft into the rock, and the tools are withdrawn. Casing pipe is inserted into the hole and a 15-ft BX core barrel and bit inserted within the casing and drilling started. Water pressure supplied to the bit is controlled at 125 psi and 50 gpm, for BX bits, but varies with other sizes used. Fifteen-ft lengths of core are drilled and then brought to the surface and placed in core boxes in correct orientation. When drill cuttings are taken, a special screen is attached to the top of the casing pipe and the collected cuttings stored with the appropriate core intervals. If trouble is encountered in BX size drilling, the hole at the trouble point is reduced to AX size by merely inserting AX casing into the hole and reducing the bit size.

The drill rig is highly mobile, being skid mounted, and can be moved through most types of ground with the aid of a small bulldozer. Use of a deadman on short moves allows the rig to go under its own power when conditions are favorable.

The drill tower is built to accommodate 5, 10, or 15-ft core barrels, and 10-ft sections of A drill rod, the latter used exclusively because of the lighter weight per ft compared to B rods. The tower can be raised or lowered by use of the drill rig winch and is quite timesaving in moving, when power lines and other overhead obstructions are encountered. For deephole drilling, a tower which accommodates two drill rod sections, 20 ft, was used to hasten removal of up to 1800 ft of drill rod from one drill hole. This tower was essentially the same as the shorter one, but had provisions for a man at the top to uncouple the rod sections.

In churn drilling a 6-in. OD bit was used by the Dragon Cement Co. Overburden was drilled to the rock surface and a section of casing pipe inserted. The hole was then drilled through this casing. Samples were taken by a sample bail at footage intervals.

F. J. ANDERSON is Chief Geologist, Dragon Cement Co. Inc., Northampton, Pa.

After reviewing the 1926 churn drill logs and being unable to accurately evaluate the area, the company-owned property at Myerstown, Pa., immediately east of Lebanon was diamond drilled in the spring of 1950. This drilling was done in the Annville limestone in sections that were previously explored with churn drills. It was possible to draw indications of the structure from these churn drill samples, but there was such a wide variation present in the chemical analyses of a supposedly chemically uniform formation, that redrilling of the area was decided upon. From staff members' past drilling experience in the western states, it was urged that all future exploration be done with diamond drills, drilling BX size core where possible and AX size core when trouble was encountered.

One of the main objectives in this drilling was to check the results of several questionable churn drill holes from the 1926 exploration. These churn drill holes were located accurately and a diamond core hole drilled within a 2-ft radius of the churn drill hole. Fourteen churn drill holes were thus checked, and a partial tabulation of the check results obtained is shown in the table.

Sample Interval	Churn Drill Holes	Diamond Drill Holes
	B-17	50-45
9 to 49 ft	93.78% $CaCO_3$	95.63% $CaCO_3$
49 to 94 ft	93.10% $CaCO_3$	95.55% $CaCO_3$
	A-11	50-33
5 to 75 ft	94.17% $CaCO_3$	95.74% $CaCO_3$
	30	50-34
0 to 50 ft	95.62% $CaCO_3$	96.10% $CaCO_3$
	B-18	50-2
5 to 65 ft	82.82% $CaCO_3$	96.41% $CaCO_3$

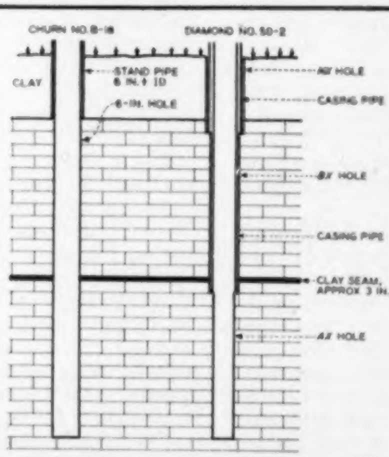
Diamond drilling raised the grade of the limestone considerably, but, with the exception of the last comparison, the indications are that limestone is present—so why dispute a few percentage points difference? One primary reply to this is that the higher the grade the more attractive the limestone is to consumers and the less tonnage they must import. Many of the Lehigh Valley cement plants import limestone to raise the $CaCO_3$ content of their raw mixes, and many of these plants specify a stone that must have in excess of 95 pct $CaCO_3$. This illustrates that it is possible to drill and sample an area with churn drills, and after interpreting the results, to misclassify the area as unusable because the grade is less than 95 pct $CaCO_3$.

The last comparison in the table brings out a most important point concerning the merits of diamond drilling. The churn drill log for hole No. B-18 showed analyses that were typical of the Myerstown formation, the overlier of the Annville limestone. The limestone of the Myerstown formation is quite siliceous, has generally less than 85 pct $CaCO_3$, and greatly resembles the Jacksonburg cement rock. The geologic plan for this area made it virtually impossible for the Myerstown to occur here, and upon offsetting this hole with diamond core hole No. 50-2 the reason it was apparently Myerstown came to light. At 40 ft in the diamond drill hole a clay seam, 3 in. thick, was encountered. Hole size was reduced to AX, casing off the part of the hole already drilled, and drilling a smaller diameter core. The hole was carried to completion after this change. The analyses of the churn drill samples, which were thoroughly washed prior to analysis, show a definite contamination from clay washing into the hole or catching in the sampling bail during raising and lowering. The diamond drill cores showed only high grade Annville limestone well past this clay seam. This example shows that churn drilling can provide indications—but sometimes even the indications are wrong. This one diamond drill hole opened up an area that heretofore was thought completely useless, and added greatly to the overall tonnage of high grade limestone available.

Other chemical compounds than $CaCO_3$ enter into this comparison of the two drilling methods. For cement manufacturing purposes, silica (SiO_2), iron oxide (Fe_2O_3), and alumina (Al_2O_3) are also important. Magnesium oxide (MgO) calculated to magnesium carbonate ($MgCO_3$) is most important in cement manufacturing, but no comparisons are made here since the $MgCO_3$ content will be low when 95 pct $CaCO_3$ is present. In the churn drill and diamond drill sample analyses, these compounds were reported, and additional comparative data made available. The table below illustrates some of these comparisons.

Sample Interval		Churn Drill Holes			Diamond Drill Holes	
	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
		B-17			50-45	
9 to 49 ft	2.71	0.61	0.82	1.60	0.20	0.50
		A-11			50-33	
5 to 75 ft	2.31	0.41	0.92	1.40	0.20	0.76
		40			50-34	
0 to 50 ft	2.00	0.40	0.70	1.30	0.20	0.51
		B-18			50-2	
5 to 65 ft	11.35	2.00	3.21	1.10	0.20	0.46

Note that all analyses for silica, iron oxide, and alumina in the diamond drill holes are lower than those for churn drill holes. It is believed that this is a result of the ability to seal off a diamond drill hole with casing, where clay seams encountered in



LEFT: Top casing being driven by 275-lb hammer that is raised by rig winch and allowed to fall free against jar coupling. CENTER: Section through completed drill holes compares churn and diamond drilling. In the latter hole, NX size is first drilled 1 ft into rock, then 2⅞-in. casing is inserted and driven, BX size is drilled to clay seam, and finally seam is cased with 2¼-in. pipe and hole completed AX size. Contamination of diamond drill samples from overburden or clay seams is impossible, and drill core accurately reveals exact thickness of clay or other unwanted material. With churn drilling, analyses and plotting of data on limestone was undependable.

Diamond Drilling Costs

Average drilling costs at Northampton for one month, two units operating:

1.	Labor, 4 men	$1,311.83
2.	Supplies and rig moving with bulldozer	491.18
*3.	Amortization of drill rigs	641.11
	TOTAL COST	$2,444.12
**4.	Total feet drilled—22 days	1,474.00 ft
5.	Total cost divided by Item 4	$1.658 average cost per ft.

*An amortized cost per ft for both rigs over 20,000 ft of drilling.
**Includes 178 ft of NX drilling through overburden and into rock.

churn drilling cannot be sealed off. In churn drilling, after the overburden has been drilled, a section of casing pipe is inserted into the hole and driven down as far as possible, but usually not into the rock. In diamond drilling, the overburden is drilled and the rock penetrated and cored for approximately a foot. After drilling, the tools are withdrawn from the hole and casing is driven tightly into the rock, providing an almost perfect seal against clay infiltration. The hole is then flushed out with water and drilling started in what is and what should remain a clean hole insofar as the seepage of clay is concerned. The inability to seal this contact point in churn drill holes allows occasional clay to enter, thus contaminating the sample and giving the higher silica, iron, and alumina values and the consequent lower calcium carbonate values. Even excessive washing to the churn drill bail samples fails to remove all contamination.

At Northampton, several tests of this top seal were run to see how effective it was in keeping clay out of the hole. A stream of water approximating 40 gpm at 140 psi was jetted against and around the top casing pipe for periods up to 30 min. During this time the top seal was observed and only negligible water came into the hole. All samples except drill cuttings were thoroughly washed.

Although emphasis has been placed on the sealing of a drill hole at the clay-rock contact, subsurface clay seams will contaminate a sample and provide false results. With proper casing in diamond drilling, contamination is virtually eliminated.

After completion of the Lebanon project, a two-year drilling program was started at Northampton, Pa., in the upper or cement rock member of the Jacksonburg formation. Lengthy records from previous churn drillings had been examined in detail, and on this further diamond drilling was planned and carried out. The differences in analytical values observed at Myerstown were small, for the most part, compared to those found at Northampton where over 25 churn drill holes were checked with diamond drill offset holes. Areas previously thought to be useless for cement manufacturing have actually become highly useful and the overall reserves at Northampton were greatly increased by this diamond drilling program.

In addition the diamond drill is a far better tool than the churn drill for exploration in that 1) it is easily maneuvered (1 hr elapsed time after finishing a 300-ft hole, withdrawing tools, moving drill, platform and equipment, laying water line, and starting a new hole), 2) a hole can be drilled at any angle into the ground, and 3) with the proper machine, holes can be drilled to much greater depths than with churn drills. One BX hole at Northampton was drilled to 1800 ft. The rate of penetration is exceedingly high. At Northampton as much as 110 ft of AX core was drilled in hard, dense, siliceous cement rock in 6¼ hr total drilling time, and an average of 65 ft of BX core hole per 6½ hr drilling time per day. Core recovery at Northampton averaged over 98 pct.

One disadvantage of diamond drilling is that large amounts of water must be used as coolant for the bits. In all Dragon Cement Co. drilling, water has been readily available. In some areas, it must be trucked to the rig, but this extra cost is usually offset by the type of information gained.

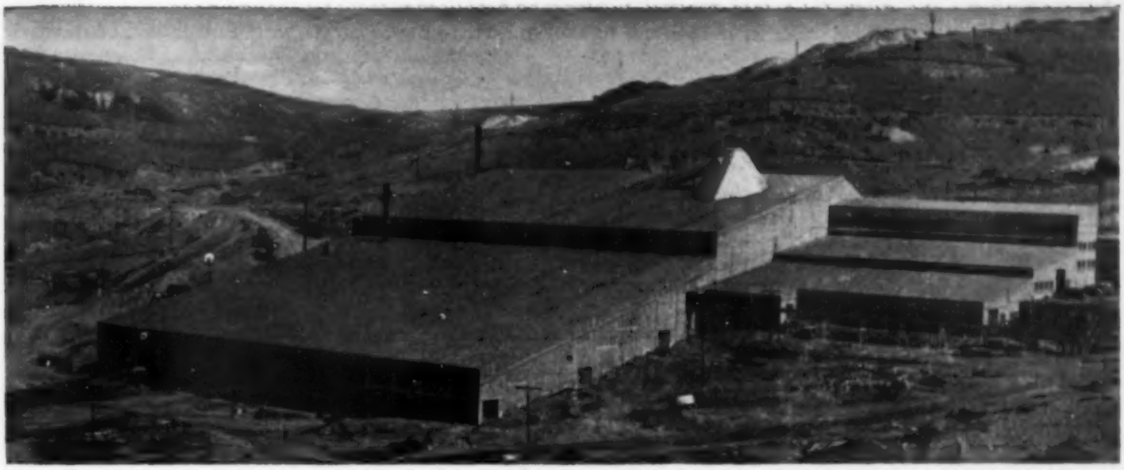
The most outstanding feature of diamond drilling, of course, is that an actual section of the rock is observed at the surface. The first churn drill hole checked at Northampton showed 21 ft of clay, then solid rock. Actually, there was only 11 ft of clay present, plus a weathered zone of cement rock that was not noted or sampled with the churn drill. The weathered zone was actually cored with the diamond drill by using special double tube, swivel-type core barrels where the inner tube remains relatively stationary. This same type of barrel cored clay seams at depth. Such information is extremely valuable in planning new quarry developments, for additional equipment must be considered to provide clean rock for manufacturing purposes. In this case, discovery of the weathered zone at the rock surface altered the planned stripping operations.

In churn drilling, it is very difficult to make a clean break between sample intervals, since even under the strictest supervision the sampling bail does not collect the entire sample. As a result, the next sample taken has a carryover of material from the previous drilled interval.

In both diamond and churn drilling, when the top casing pipe is not driven or drilled into the rock, the shifting of this pipe often causes the loss of the hole in addition to excess contamination. In diamond drilling, the use of casing shoe bits, which are drilled into the rock and remain there until the hole is completed, is often more advantageous than the use of NX bits and casing, used by the Dragon Cement Co. Casing shoe bits have their limitations, the prime one being the type of overburden drilled.

The services of a great number of contract drillers are available today throughout the U. S., and although the Dragon Cement Co. used these facilities for two years, it eventually purchased two drilling rigs to maintain closer control over the entire exploration program, because a large enough footage had been planned to warrant the capital investment. This work was highly successful, not only from the standpoint of closer control over the projects, but also from the cost side. Churn drilling can be done for less than diamond drilling, but it is felt that the cost differential is offset by the type of information gained. Northampton drilling costs averaged less than $1.75 per ft of core drilled, including all sizes.

This article is by no means to serve as an indictment against use of the churn drill in exploration for it, like any piece of equipment, has a place under the proper conditions. Rather, the purpose is to show that for this particular instance, only diamond drilling could provide satisfactory answers. In the case of the Dragon Cement Co., the conditions were ideal for diamond drilling, and the comparisons between diamond drill and churn drill samples, as previously brought forth, actually made diamond drilling compulsory. If the company had been seeking indications, churn drilling would have been satisfactory, but in seeking accuracy of analyses in addition to the indications, only diamond drilling would suffice.



Operation of FluoSolids Roaster at Golden Cycle

by Howard R. Keil

Reactor at Carlton mill successfully calcines pyrite-telluride flotation concentrate for cyanidation.

CARLTON mill in the Cripple Creek district, 45 miles southwest of Colorado Springs, Colo., has been in operation for approximately three years, treating the custom sulpho-telluride ores formerly handled by the Golden Cycle mill in Colorado Springs. At the new mill the pyrite-telluride flotation concentrates have been roasted, prior to cyanidation, in a Dorrco FluoSolids reactor, which has proved capable of yielding calcine readily amenable to cyanidation.

Incoming ores are crushed at Carlton to ⅝ in. and sampled in 30 to 75-ton lots before the individual lots are mixed in the fine ore bin. The composite ore then goes to the grinding circuit. Classifier overflow from the grinding circuit is treated by flotation to produce a concentrate containing approximately 85 pct of the values in 5 pct of the weight. The flotation concentrate goes to the FluoSolids reactor prior to cyanidation. Cyanide solution values are recovered by zinc dust precipitation. Flotation tailings are thickened and cyanided, the values from this part of the circuit being recovered from solution by activated carbon.

Gold values in the flotation concentrates consist of a small amount of finely divided metallic gold; the tellurides, sylvanite and calaverite; and gold very intimately associated with the pyrite.

The metallic gold and a part of the telluride values can be extracted from the concentrates by cyaniding without roasting. However, extraction on the tellurides by this method is not satisfactory, and the pyrite values are so intimately associated with the pyrite that very fine grinding and cyanidation for a prolonged period under ideal laboratory conditions does not yield good recovery.

Upon roasting, the tellurides are oxidized to very finely divided metallic gold which is readily soluble in cyanide. The pyrite is oxidized mainly to a porous iron oxide which allows cyanide solution to penetrate to gold particles and take them into solution.

Feeding the Reactor

Flotation concentrates move by gravity to a thickener. Thickener underflow is discharged at approximately 60 pct solids, by means of a diaphragm pump, into a storage and blending agitator. From here the concentrates are pumped to a disc filter. The filter cake, at 84 to 88 pct solids, drops directly into a repulper where it is repulped into a slurry of 78 to 80 pct solids. The repulped filter cake flows into a 6x6-ft slurry agitator from which it is fed directly into the reactor by the Moyno pump.

The Moyno pump has eliminated a large number of difficulties that were first encountered in feeding a wet concentrate to the reactor. On the original installation in Canada a screw feeder was used to introduce the filter cake directly into the reactor. Since the reactor is under a slight positive pressure it was necessary to have a suitable seal to prevent gas escaping from the reactor at this point. When the concentrates produced in flotation were coarse or granular they could be readily fed to the reactor but when fine-textured, clayey concentrates were produced a great deal of trouble was encountered.

H. KEIL, Member AIME, is Mill Superintendent, Carlton Mill, Golden Cycle Corp., Cripple Creek, Colo.

Discussion on this paper, TP 3919B, may be sent (2 copies) to AIME before Jan. 31, 1955. Manuscript, Jan. 14, 1954. New York Meeting, February 1954.

The Transactions papers appearing in Mining Engineering during 1954 will subsequently appear in AIME Transactions Vol. 199 and may be permanently referenced to that volume.

By repulping the filter cake into a very thick slurry that will just flow, and then feeding this slurry into the reactor with a Moyno pump, it is possible to eliminate these troubles.

The concentrates are fed into the reactor at a point, in plan, directly opposite the main overflow opening and, in elevation, approximately 6 in. above the fluidized bed. A short length of 1½-in. black pipe, flattened and pointing downward at the end at approximately 30° below the horizontal, extends into the reactor 8 in. beyond the inside of the refractory lining. This feed pipe sprays the concentrate down into the fluidized bed. A small amount of compressed air is fed into the feed pipe just before it enters the roaster. This helps to give a spray effect and also serves to cool the feed pipe inside the reactor during shutdown periods.

Roasting the Flotation Concentrates

Temperature control in calcining gold-bearing pyrite for subsequent cyanidation is believed to be of prime importance. In the FluoSolids reactor a very close degree of temperature control is realized with a uniform temperature condition readily maintained throughout the fluidized bed. Under normal operating conditions there is no appreciable temperature difference between different parts of the bed. Heat released during the reaction is immediately distributed throughout the entire bed with no apparent overheating at any point. As long as the sulphur content of the feed is high enough to obtain the desired bed temperature the temperatures can be maintained within a few degrees. Any excess heat released can be controlled by spraying cooling water directly on the fluidized bed or, as is the case at the Carlton mill, by adding additional water into the feed at the discharge of the Moyno pump.

It has been found at the Carlton mill that a concentrate assaying between 19 and 20 pct sulphur must be obtained in order to maintain a self-sustaining roast with a feed containing 20 to 22 pct moisture. However, under nomal operation, a 22 to 23 pct sulphur concentrate is maintained to give a greater factor of safety.

At the present time the reactor roasts between 35 and 40 tpd of concentrates. Since it has a rated capacity of 60 tons per 24 hr, it is operated intermittently 14 to 16 hr per day. It can be shut down and started up without difficulty and without any apparent disturbance in metallurgy or extraction. The bed holds its temperature for a considerable length of time; the reactor has been shut down for periods as long as 36 hr and started again without the addition of fuel. Since there are no moving parts within the reactor itself, all that is required in shutting down is to cut off the feed and air. In starting up, the air is turned into the windbox first and then the feed pump is started.

For longer periods of shutdown an auxiliary fuel oil burner attached to the reactor just above the fluidized bed is used to bring the bed back up to roasting temperature. Also, if sulphur content of the feed falls below a certain point it becomes necessary to put the auxiliary oil burner on for short periods to hold the temperature. At the Carlton mill, however, the reactor has been operated intermittently for periods as long as four months without using any auxiliary fuel.

Since all air is introduced into the reactor by a blower, the degree of oxidation of the calcine can be readily controlled. Calcines ranging from black through shades of chocolate brown to bright red can be produced merely by changing the amounts of feed and air to the reactor. On the black end of the scale practically all the iron is present as magnetite. On the other end of the scale all the iron is present as ferric oxide or hematite. Intermediate products range from red to black in shades of chocolate brown and contain various mixtures of hematite and magnetite.

During the first six months of operation of the reactor a bright red roast was maintained, operating with from 50 to 100 pct excess air. Cyanide residues on the calcines were erratic and were considerably higher than the original tests indicated they should be. The roast was then changed to produce a chocolate-colored calcine, with approximately 1 pct O_2 in the exhaust gases. Since that time very consistent results with good cyanide residues have been obtained. It is believed at the Carlton mill that these results are obtained with the chocolate roast for the following reason. In a single compartment FluoSolids reactor the feed is brought into a zone of maximum temperature almost immediately. If there is a large excess of oxygen present in the freeboard section of the reactor, along with the high temperature, ideal conditions prevail for an instantaneous roast on some of the very finely divided particles. With an instantaneous roast it is conceivable that some of these individual particles reach temperatures several hundred degrees in excess of the bed temperatures and thus lock up some of the gold values to subsequent cyanidation. Holding the excess oxygen to a minimum in the freeboard minimizes the possibilities of instantaneous roasting.

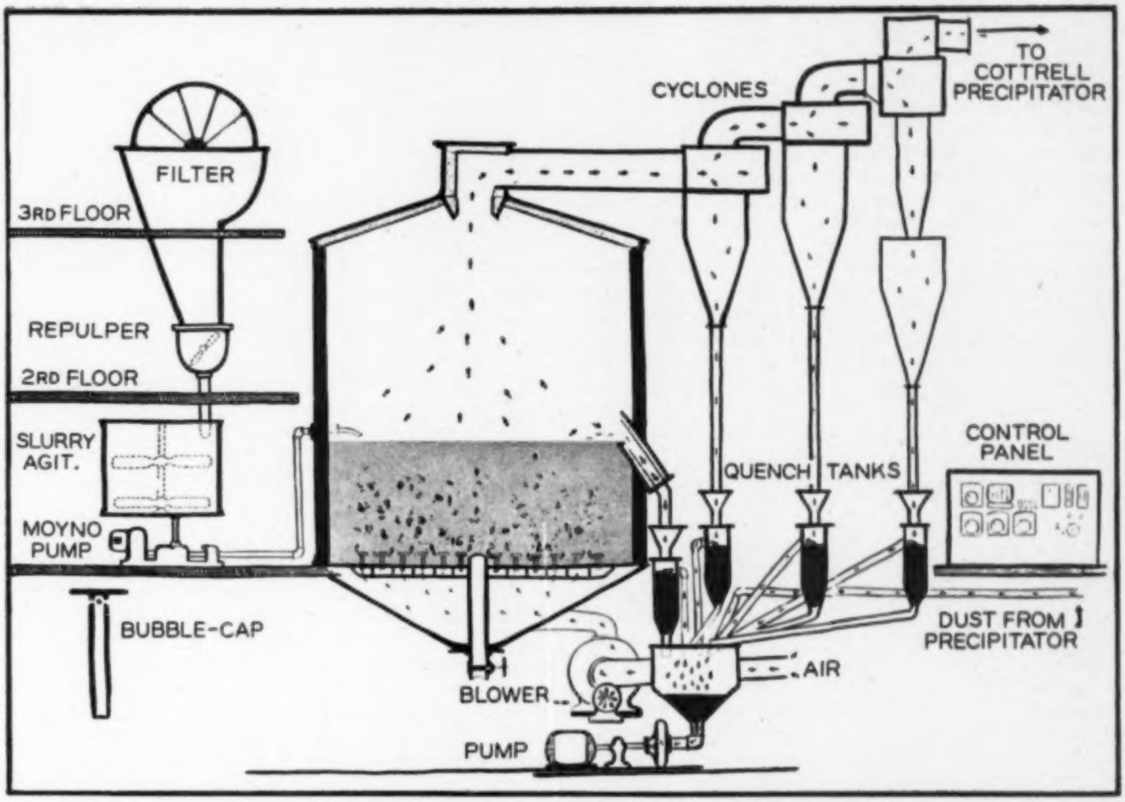
Table I. Operating Conditions and Results of Experiments at Carlton Mill, December 1952

Test number	1	2	3
Color of calcine	Black	Chocolate	Red
Bed temperature, °F	1150	1150	1150
Freeboard temperature, °F	1040	1045	1060
Fluidizing air, cfm	1100	1100	1200*
Feed rate, lb per hr dry solids	4250	4050	3830
Feed, pct solids	79.1	79.5	80.0
Feed, pct sulphur (total)	22.4	22.9	24.3
Feed, pct iron (total)	21.4	22.4	23.1
Feed, pct insoluble	45.6	44.7	41.3
Cooling water, gpm	1.5	1.3	1.9
Stack gas composition			
SO_2, pct		14.9	12.2
SO_3 plus CO_2, pct		1.9	2.1
O_2, pct		0.8	2.1
Excess air (with reference to Fe_3O_4), pct	2.0	4.5	11.6*
Calcine, Fe_3O_4 (calculated), pct	25.35	15.46	1.10
Calcine, Fe_2O_3 (calculated), pct	6.99	15.38	36.03
Calcine, FeS (calculated), pct	1.5	1.5	0.5
Cyanidation test results			
Recovery, Au, pct	88.10	91.40	94.70
CaO consumed, lb per ton dry solids	7.22	6.82	8.61
NaCN consumed, lb per ton dry solids	4.58	3.44	2.58

* Set low to prevent overloading of cyclones.

Along this line, the results of some experiments made by F. L. Bosqui and H. W. Richards of the Dorr Co.[1] working with the staff of the Carlton mill in December 1952 may be of interest. As many performance data as possible were collected under operating conditions adjusted to give black, chocolate, and red calcines respectively. Samples of feed and calcines were returned to Westport for further tests and study. Operating conditions and results are shown in Table I.

It should be noted that although test No. 3 showed the highest gold recovery and lowest cyanide consumption, this test was not a typical red roast. The excess air during this test was only 11.6 pct, whereas normal red roasts are made at 50 pct excess air or better. Sulphating conditions at 50 pct excess air



The FluoSolids Reactor and Auxiliary Equipment

The FluoSolids Reactor or Roaster

1—The cylindrical shell of ¼-in. steel plate, 16 ft 6 in. high, ID 16 ft 6 in. This inside diameter is reduced to an effective diameter of 14 ft, 0 in. in the lower or *bed* section of the reactor by a refractory lining 9 in. thick backed with 6 in. of insulating brick. This heavy refractory lining is carried up from the bottom of the shell for a distance of 5 ft 0 in. or to a level corresponding with the main overflow outlet of the reactor. In the upper or *freeboard* section of the cylindrical shell the diameter is reduced to an effective diameter of 15 ft, 0 in. by a refractory lining 4½ in. thick backed with 4½ in. of insulating brick. Openings are provided through the steel shell and lining for pressure taps, thermocouples, inspection ports, auxiliary burner ports, and feed and discharge connections.

2—The conical shaped windbox attached to the lower end of the cylindrical shell, into which the air is introduced for fluidization. No refractory lining is required in the windbox.

3—The domed top with opening in the center through which the exhaust gases are carried, along with a certain portion of the calcines. The top, like the cylindrical shell, is lined with refractory brick but is backed by a light weight castable insulating refractory cement instead of insulating brick.

4—The constriction plate, fabricated of ⅞ in. mild steel plate reinforced on the bottom side with ½x6-in. steel bars, on edge, spaced on 12-in. centers to resemble a huge waffle iron. The constriction plate has the same diameter as that inside the refractory lining in the lower section of the cylindrical shell, namely, 14 ft, 0 in. There are 134 openings in the plate spaced on 12-in. centers, each opening being tapped with 1-in. standard pipe treads. In each of these openings is screwed a stainless steel *bubble-cap* or tuyere which looks like a piece of 1-in. pipe, approximately 9 in. long, with a 3-in. diam plate, ¼ in. thick, covering the top of the pipe. Immediately under the top plate or cap are four ¼-in. holes, located on quarter-points, through the wall of the pipe. The pipe is threaded on the lower end to fit the threads in the openings in the plate. The constriction plate is covered with two 3-in. layers of refractory brick, laid in such a manner as to leave a 4-in. square opening around each bubble-cap or tuyere. These openings are filled with gannister or crushed fire brick. The bubble caps act as distributing valves for the diffusion of air throughout the bed, and as check valves when the reactor is shut down, to prevent calcine from passing down through the openings in the constriction plate into the windbox below. Through the windbox and constriction plate is fitted an 8-in. pipe with an outside valve for emptying the reactor when necessary.

The Auxiliary Equipment

1—A Spencer turbine type of blower furnishes all the air for the reactor, introducing it through the windbox. The blower is driven by a direct-connected 125-hp, 3450-rpm motor and is capable of delivering 3200 cfm air and 5 psig. The amount of air to the reactor is controlled very readily by a blast gate or butterfly valve on the discharge side of the blower. At the present time 1100 cfm of air are being fed into the wind-box of the reactor at the Carlton mill, consuming approximately 80 hp.

2—A Moyno pump with tool steel rotor and soft rubber stator is used for pumping the raw concentrates into the reactor in the form of a thick slurry of from 78 to 80 pct solids. This pump is driven by a 3-hp direct-connected U.S. Varidrive motor. Rate of feed is controlled by the speed of the pump.

3—Two 42-in. Western Precipitation cyclones and one 24-in. two-tube Western Precipitation multiclone, all connected in series, receive the exhaust gases from the opening in the domed top of the reactor. The connecting ducts, the cyclones, and the multiclone are lined with a castable refractory cement.

4—A Cottrell precipitator receives the exhaust gases from the multiclone before they are discharged up the stack to atmosphere.

5—Four quench tanks receive, respectively, the hot calcine from the main overflow opening of the reactor, the products from each of the two cyclones, and the product from the multiclone. The Cottrell precipitator product is removed from collecting hoppers by means of a screw and is discharged into a stream of water that combines with the discharge from the four quench tanks into a common receiving tank or sump, the contents of which are pumped to the calcine cyanide section of the plant.

would cause a sharp increase in cyanide consumption and a decrease in gold recovery.

There is no direct visual means of observing what is happening within the reactor, but by observing temperature recorders and pressure differential instruments on a control board, one can understand what is occurring and make the necessary adjustments and changes.

Temperature control is simple, consisting of injecting water into the fluid bed or adding additional water with the feed. This is accomplished with an automatic bed temperature recorder controller that automatically opens an air-operated water valve when the temperature reaches a certain point. It has been found at the Carlton mill that a smoother temperature curve can be maintained by operating the cooling water valve manually. Thermocouples are installed in the windbox, bed, and freeboard and in the duct at a point just ahead of the Cottrell precipitator. These four temperatures are recorded continuously throughout any period of operation.

A series of draft gages is mounted on the instrument panel to measure pressure and pressure differentials at and between various points of the reactor and the gas ducts. Gages are connected in such a manner as to measure: 1—total pressure in the wind box in psi (static), 2—pressure drop through the constriction plate in inches of water, 3—pressure drop through the reactor bed in inches of water, 4—pressure drop through the cyclones and connecting ducts in inches of water, and 5—actual duct pressure at a point just ahead of the Cottrell precipitator in inches of water. Any changes in readings of the various draft gages indicate to the operator that some change has taken place within the reactor circuit.

The amount of fluidizing air entering the windbox of the reactor is readily controlled by a blast gate or butterfly valve on the discharge side of the blower. The flow of air is measured by means of an orifice plate and is indicated on a transmitter as well as being recorded on an airflow recorder.

A slurry density recorder-controller was also provided for the reactor feed. This instrument has never worked properly and consequently has never been used. The operator controls the density of the slurry in the agitator by eye. At first, weights were taken on a density scale, but it was soon found that the slurry had a definite appearance as far as fluidity was concerned. Between 80 and 82 pct solids the slurry becomes very doughy and can be balled up and stuck on a wall. At 78 to 80 pct solids it becomes quite fluid and can be readily pumped with the Moyno pump.

The color of the calcine is controlled by the operator by eye. The color of the calcine coming from the Multiclone quench tank is always used as the standard since any change is reflected rapidly and positively at this point. The amount of air to the windbox and the bed temperature are set as constants for the operator. Holding these two conditions constant, he then regulates the feed to the reactor to give the desired color of calcine. This automatically takes care of small changes of sulphur content in the feed and also changes of rates in feed due to consistency of the slurry to the Moyno pump, feed head on the pump, and wear on the pump parts. This method of control has proved satisfactory.

Typical operating data as regards to temperatures and pressures are presented in Table II.

It is imperative that ample dust-collecting equipment be provided when a high-grade flotation concentrate is roasted. Under present operating conditions, approximately 60 pct of the calcine is collected in the main overflow quench tank and approximately 40 pct is carried over with the exhaust gases. The exhaust gases pass through two 42-in. Western Precipitation cyclones and one two-tube 24-in. Western Precipitation multiclone, all connected in series, before entering a Cottrell precipitator. The exhaust gases from the Cottrell precipitator enter a stack and are exhausted to atmosphere. Operation of the reactor was started before completion of the Cottrell precipitator, with only the two cyclones and multiclone in the circuit. However, stack losses were found to be excessive and after several months of operation the reactor was shut down until construction of the Cottrell precipitator was completed.

Table II. Typical Operating Temperatures and Pressures

Air to windbox, cfm	1100
Bed temperature	1150*
Windbox temperature	200
Freeboard temperature	980
Duct temperature (gases entering Cottrell)	590
Windbox pressure, lb per sq in.	2.7
Pressure drop through constriction plate, inches H_2O	24
Pressure drop through reactor bed, inches H_2O	47
Pressure drop through cyclones and connecting ducts, inches H_2O	8.9
Duct pressure (entering Cottrell), inches H_2O	0.6

* All temperatures are in °F.

Table III. Size Analysis and Distribution of Feed and Products, Test No. 2, Table I

Particle Size, Mesh	Particle Size, Microns	Feed, Pct Cumulative Plus	Overflow, Pct Cumulative Plus	1st Cycle, Pct Cumulative Plus	2nd Cycle, Pct Cumulative Plus	Multiclone, Pct Cumulative Plus	Cottrell, Pct Cumulative Plus
35	417	0.1	0.2				
48	295	0.5	0.9				
65	208	3.1	5.2	0.2			
100	147	11.6	21.0	0.7	0.3	0.6	
150	104	24.5	46.3	1.7	0.6	0.8	
200	74	35.6	65.3	2.6	0.8	1.6	
	60	45.5	81.8	2.7	0.9	4.0	
	40	60.0	94.15	10.5	1.0	14.0	
	30	66.8	96.4	22.0	2.0	31.0	
	20	75.1	97.62	42.0	4.0	59.0	
	10	85.0	98.46	66.5	22.0	86.0	
	8	87.2	98.6	72.0	29.0	90.6	22.2
	5	91.0	100.0	81.5	45.0	96.0	45.0
Weight, pct			59.4	30.75	4.06	2.56	3.23

Table IV. Chemical Analyses of Feed and Calcines, Test No. 2, Table I

	Au Oz Per Ton	Total S, Pct	Soluble S, Pct	Sulphide S, Pct	Total Fe, Pct	Ferrous, Pct	Ferric, Pct	Insoluble, Pct
Feed	8.55	22.9		22.9	22.4			44.7
Overflow	4.50	1.0	0.8	0.2	14.5	2.6	11.9	70.0
1st Cyclone	15.67	11.4	0.6	0.8	40.7	11.3	29.4	31.4
2nd Cyclone	18.04	1.4	0.4	11.0	39.0	14.5	24.5	32.3
Multiclone	17.77	1.2	0.5	0.7	32.7	9.3	23.4	40.2
Cottrell	7.47	2.8	2.7	0.1	32.8	2.9	29.9	36.2

Table III shows a size analysis of the feed to the reactor and of the various calcine products from the reactor as well as the percentage distribution of these products. Table IV shows a chemical analysis of the feed to the reactor and of the various calcine products from the reactor. The data in Tables III and IV were obtained from analyses of samples collected in test No. 2, Table I.

During the two and a half years operation of the FluoSolids reactor there has been very little main-

tenance required. There has been no replacement or repair on the refractory lining. This appears to be almost as good as when it was installed.

After six months of operation the bed was drained from the reactor and all the bubble caps or tuyeres removed for checking. There were no signs of corrosion, but a large number of them were sandblasted on the bottom side of the cap. The ¼-in. holes through the wall of the pipe, immediately under the cap, were all tapered from the inside to the outside when the bubble caps were fabricated. This allowed the air to blast up against the bottom side of the cap, carrying coarse calcine with it and producing a definite sandblast effect. The bubble caps were all repaired by welding and all the ¼-in. holes were filled in so that instead of tapering out in all directions, they sloped downwards slightly. Again, after an additional 14 months of operation the bed was pulled down in the center so that 8 or 10 bubble caps could be reached. These were inspected, in place, and all appeared to be in good condition, no additional sandblasting having taken place.

The reactor feed pipe is replaced every five to six weeks. This is a short piece of 1½-in. black iron pipe, about 18 in. long, threaded on one end and flattened and turned down slightly on the other end.

At the present time the Moyno rotors and stators are lasting three to five months. Adding the cooling water to the discharge of the Moyno pump has seemed to prolong the life of the wearing parts considerably. The rotors have been built up by welding and ground down to give a tight fit on a companion stator. These built-up rotors will ordinarily run for a period of about a month. Some have been built up as much as three times before being discarded.

The quench tanks are all constructed of mild steel and it has been necessary to replace certain parts that have eaten out due to corrosion. The 6-in. seal pipe in the main overflow quench tank must be replaced every two or three months. Seal pipes in the other three quench tanks have been replaced once since the start of operation.

Four diaphragms on the draft gages have been replaced and the vibrator unit on each of the two temperature recorders has been replaced since the reactor was put into operation.

The original steel stack lasted approximately 16 months. As is always the case with steel stacks, there is considerable corrosion above the point where the temperature reaches the dewpoint, resulting from the formation of weak sulphuric acid. A light gage stainless steel stack is being contemplated for the future.

Table V. Roasting Costs, Jan. 1, 1953 to June 30, 1953

Item	Cost per Ton of Head Ore, $	Cost per Ton of Concentrates, $
Labor (operating)	0.044	0.932
Power	0.048	1.052
Water	0.007	0.153
Royalties, materials, and supplies (operating)	0.017	0.381
Repair labor	0.031	0.678
Repair materials and supplies	0.035	0.707
Total	0.182	3.903

Roasting costs are broken down to include all costs starting with the filtering of the concentrates and carrying on through until the gases are discharged to atmosphere. These costs include the filter, repulper, slurry agitator, Moyno pump, reactor, cyclones, Cottrell precipitator, stack, quench tanks, Spencer turbine, and 2-in. centrifugal pump that delivers calcines to the cyanide circuit. Table V gives a break-down of these costs, as referred to above, for a period of from Jan. 1 to June 30, 1953.

The products from the four quench tanks, plus the product from the Cottrell, are all combined in a collecting sump. Enough milk of lime is added at this point to give a concentration of 0.25 to 0.35 lb CaO per ton of solution in the first calcine cyanide agitator. The pulp from the collecting sump, at 8 to 12 pct solids, is pumped by means of a 2-in. Wilfley pump to a 30-ft diam thickener. Thickener underflow is discharged by means of a diaphragm pump, at 40 pct solids, to the first of two 14x16-ft agitators. Aero brand cyanide is fed to the first agitator by a screw feeder to maintain a strength of 1.0 to 1.25 lb NaCN per ton of solution in the first agitator.

Overflow from the second agitator flows by gravity to the first of two 30-ft diam countercurrent washing thickeners. Enough barren solution is added to the second thickener to furnish 540 tons of overflow solution per 24 hr from the first thickener. This solution is clarified and precipitated by the Merrill-Crowe zinc dust precipitation process.

Underflow from the second countercurrent thickener is pumped to a 24x16-ft agitator, the overflow of which is filtered and washed on an 8x10-ft Oliver drum filter. The filter cake is repulped in barren solution and flows by gravity to the flotation tailings cyanide circuit.

Table VI shows some data on concentrate assays, calcine assays, extraction, and chemical consumption over a six-months period.

Table VI. Average Assays, Extraction, and Chemical Consumption, Jan. 1, 1953 to June 30, 1953

Flotation concentrate, Au, oz per ton	5.53
Flotation concentrate, pct sulphur	23.9
Calcine heads, Au, oz per ton	6.68
Calcine tails, Au, oz per ton	0.17
Calcines, pct extraction*	97.5
NaCN consumption, lb per ton calcine	5.19
CaO consumption, lb per ton calcine	9.50

* Additional extraction is obtained on calcines in low grade agitators.

In conclusion, the results obtained to date with the FluoSolids reactor have been very satisfying. The entire system operates smoothly and can be shut down and started up with ease. With the close control of temperature and air input obtainable it should have great possibilities in roasting many materials other than gold-bearing concentrates.

Acknowledgments

The writer wishes to thank Max W. Bowen, General Manager, Charles F. Stanley, Metallurgist, Earl C. Phillips, Chief Engineer and Electrician, and other members of the staff of the Golden Cycle Corp., also T. B. Counselman, F. L. Bosqui, and H. W. Richards of the Dorr Co., for their helpful information, encouragement, and many valuable suggestions in the preparation of this paper.

References

[1] F. L. Bosqui and H. W. Richards: Final Report on Performance of the Golden Cycle Corporation's 14-Ft Diameter Gold Concentrate FluoSolids Reactor Located at the Carlton Mill, Cripple Creek, Colorado M.O. 52239-DD1296 A.J.

[2] Owen Matthews: FluoSolids Roasting of Arsenopyrite Concentration at Cochenour Willans. *Canadian Institute of Mining and Metallurgy Bulletin* (1949) **52**, pp. 97-106.

Diamond Drilling Problems at Rhokana

by O. B. Bennett

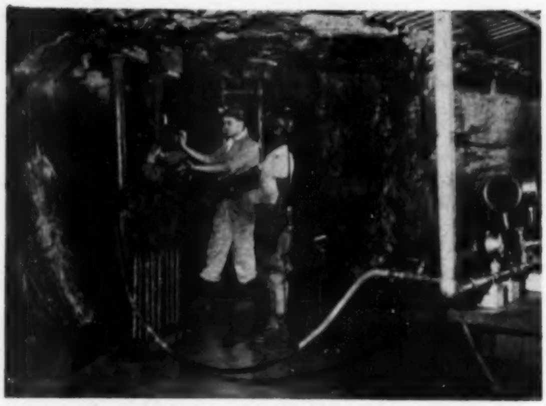


Fig. 1—General view of experimental drilling in test chamber.

WHEN diamond drilling was introduced in the Rhokana mines in 1939 it was used principally for pillar removal and for completion of the upper portions of shrinkage stopes which were being affected by increasing pressure. This method of drilling long blastholes proved so successful that it was extended gradually to cover stoping, pillar recovery, and hanging cave work. By 1949 virtually all the production of Mindola and Nkana was being obtained by this method. At the present time 87,500 ft are drilled each month by the 80 diamond drills in daily operation.

Responsibility for control and issue of diamond drilling equipment and crowns, as well as tabulation of all performance figures, was taken over by a specially formed Roto drill department, which also investigated the problems encountered with this new method. To assist this department a fully equipped test chamber, Fig. 1, was established underground where performances of various types of machines and equipment could be studied under conditions as nearly uniform as possible.

Since the establishment of this department, which was eventually taken over and incorporated into the study department, considerable experimental work has been done on every aspect of the subject. The problems can be classified broadly under four headings: improvement of drilling equipment, crown design, machines, and stoping layouts.

One of the major problems with drilling equipment has been to eliminate vibration. Owing to flexing of rods in the hole, severe friction is set up on the back end of the core barrel and on any high spots in the rods, inducing harmonic vibration in the string of rods and causing the crown to chatter against the face. This not only causes premature crown failure but also reduces penetration speeds and increases wear on the machines and rods used.

In the early days, when only holes of EX size were drilled, vibration was largely overcome by periodic greasing of rods and core barrel during each run, but with the change-over to the larger BX hole it became obvious that application of grease by hand was inefficient and time-consuming, and attempts were made to perfect a self-lubricating core barrel. A series of these core barrels was made up and tested and a number of the latest type were used under normal operating conditions, but although footages up to 120 ft were drilled without refilling the overall performance was inconsistent, and the idea was shelved in view of the success of the stabilizer rods referred to later in this paper.

At the same time tests were made with barrels 5 ft and later 6 ft long instead of the normal 2 ft. Although a slight improvement was noticed, greasing was still necessary. It was found that rod vibration increased as the core barrel became worn, and in an early test chamber experiment crowns drilled with a worn core barrel averaged 95 ft with a diamond loss of 4.76 carats, whereas the same type of crowns with a new barrel averaged 228 ft with a diamond loss of 3.13 carats.

Until then all BX drilling had been done with *B*-sized rods, but during a test on a string of BX-sized rods it was noticed that vibration was negligible. Because of the larger surface area of metal bearing on the sides of the hole, however, the friction and resistance of rods of this size rendered them impracticable on any but the most powerful of the machines.

The use of stabilizers spaced evenly along the rods was the next logical step, and for this *B* couplings, see Fig. 2, were set with three tungsten carbide inserts 1 in. long placed around the periphery equidistantly and at an angle of 45° with a right hand lead. These were placed immediately behind the core barrel and then at 12-ft intervals, as it was found that vibration still occurred when the stabilizers were more than 15 ft apart. The effect of these stabilizers was immediately noticeable; holes were drilled with a minimum of vibration, penetration speeds were improved, and as it was no longer necessary to grease the rods there was a marked decrease in the overall drilling time for each hole.

While tests were being made with the stabilizer couplings, experiments were taking place with a set of tapered threaded rods, and because there was marked improvement in efficiency it was decided to incorporate the stabilizers and tapered threading in all new rods ordered for Rhokana. The feature of these rods is that only four full turns are required to tighten the coupling as against nine for the present type of *B* rods. Also, as they are self-centering it is virtually impossible to crossthread them. Each rod has a male 5° tapered Acme thread, Fig. 3, on one end and a female at the other, so that separate couplings are unnecessary, and every fifth rod has an

O. B. BENNETT is General Manager of the Rhokana Corp. Ltd., Kitwe, Northern Rhodesia.

Discussion on this paper, TP 3931A, may be sent (2 copies) to AIME before Feb. 28, 1955. Manuscript, March 1, 1954. New York Meeting, February 1954.

enlarged section behind the male thread into which are sunk the stabilizing tungsten carbide segments.

Although the mines are not yet fully equipped with the new type of rods plus stabilizers, results obtained in areas where the rods are in use are very encouraging. The first sets were issued to a miner whose efficiency was below average. The following figures show the results obtained:

Crown life	*B* rods plus grease	71.6 ft per crown
	Tapered thread plus stabilizers	122.5 ft per crown
Footage per machine shift	Old rods	41.0 ft
	New rods	64.2 ft

In a later major crown test, the footage per reject crown with miners equipped with the new rods was 287.1, whereas that with the old type was 161.5 ft.

To determine the most suitable length further test work has been done on core barrels 5 to 8 ft long. It should be emphasized here that the core barrel used at Rhokana is fitted mainly as a stabilizing section behind a noncoring crown. As rod vibration is induced by friction on the rear end of the core barrel, it was thought that if the core barrel were reduced to 5 in., i.e., by a crown adaptor, and stabilizers were used in the string of rods, friction would be reduced to a minimum. This in fact was the case, but it was found that the deflection of holes of any length was too great to warrant their adoption. As expected, the most accurate holes were drilled with the 8-ft core barrels.

Stones: From the earliest days diamonds used in the crowns have been between 10 and 12 to the carat, and the present average is the grade known as C2, or cast-setting material running 11 stones to the carat. Until recently all stones were from the Belgian Congo, but crowns set with more expensive Premier drilling material have now been drilled both experimentally and on normal run-of-mine work. Footages obtained during initial tests with the better stones were much higher than those with Congo stones, and the costs per foot lower, but in more recent major tests the Premier set crowns have not performed as well as was hoped. Further major tests are being run at present to determine which of the two types of stone is the more economical.

Tests carried out on crowns set with small stones, 20 to the carat, gave very encouraging results, due not so much to increased footage per crown drilled as to the decreased diamond losses, which were in proportion to the weight of stones set. Five crowns with stones 40 to the carat set in an extra hard matrix were promising, although four failed prematurely because the center collapsed. The fifth, however, reached a remarkable footage of 506 ft, indicating that further tests along these lines are warranted. The size to be used is governed largely by availability, however, and as stated earlier, stones averaging 11 to the carat are set in the normal mine crowns at present.

The theory that stones become brittle and break during drilling after frequent salvage and re-use was tested in an early experiment using a particular set of stones as many times as possible. A study of results obtained indicated that the structure of some stones is naturally stronger than that of others, and that fatigue is not an important factor in stone failure, as there was a marked decrease in failures after each re-use. Further work is being done on this.

Crown Design: A careful study of each batch of crowns received from the manufacturers revealed considerable variation in the pattern of stones on the crown face.

Until then the pattern of stones on the crown had been left to the die puncher at the factory, and there was no way of knowing beforehand whether crowns from any particular master die would perform satisfactorily. It was obvious, therefore, that some method should be devised whereby the stone loading of a crown face could be determined and measured against a known series of *minimum loadings.* An official on drilling research worked out a means of calculating the number of cutting points per unit area at fixed intervals across a crown face. These figures are plotted against an average minimum loading line determined by a study of the characteristics of a number of different crowns whose loading lines had already been plotted. Using this method it was possible, by working from the master die, to determine whether crowns made from that die would have any weak spots.

It was by no means easy, however, to work back from the minimum loading line and produce on the drawing board a crown theoretically having no weak spots. A second method has therefore been evolved by a member of the manufacturing company by which the whole stone layout is plotted on a drawing and then transferred to a die plate by a photographic process perfected in the Diamond Research Laboratories.



Fig. 2 (left)—The *B* coupling with tungsten carbide insert. Fig. 3 (center)—Tapered threading and stabilizing section on new rods. Fig. 4 (right)—The BX crowns used at Rhokana mines.

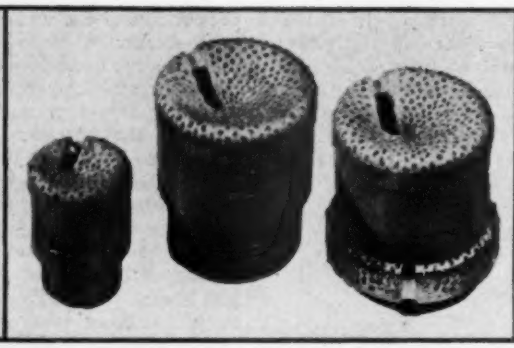


Fig. 5 (left)—Experimental BX crown showing layout of water holes. Fig. 6 (center)—Types of crowns in use at the present time. Fig. 7 (right)—Experimental crown with offset water grooves.

One major test has been run on a series of crowns that had been punched arbitrarily and checked by the first of these methods. A second test is now in progress. This particular series, the BX2 shown in Fig. 4, was chosen because its loading graph most nearly approached the theoretical line, although a weak spot was noticed during the test. This weakness is now being remedied in the BX5 crown by an increased number of stones in the underloaded area. Results were noticeably better than those obtained with the crowns previously used, the footage per reject of the BX2 rising to 163 ft from 119 ft.

BX4 test crowns made to a drawing board design are now being tested. First results indicate that they contain no inherent weaknesses and that a large-scale test is warranted. These crowns, Fig. 5, have two water holes in place of the normal one. In this design the distance between the stone centers is 125 pct of the diameter of a stone, and each stone is slightly further from the center than the one ahead of it. The diamonds thus lie in lines curving out and away from the center.

All recent test work has been done on the BX noncoring crown, but the use of a pencil coring crown offers many attractions, and a number of tests were run at Rhokana to find a suitable type for use at the mines. Advantages are: 1—reduction in the weight of diamonds set, with consequent decrease in stone losses; 2—less rock to be cut, therefore faster speed; and 3—elimination of the vulnerable center portion. Results were disappointing, however, and trouble was caused by breaking and jambing of core in the core barrel.

The only coring crowns now used, those giving a 1⅝-in. core, are drilled in ground too hard for a noncoring crown. In an attempt to perfect a continuous coring operation extra hard matrix was used in these crowns, together with rods flush-jointed on the inside, but no notable success was achieved.

In addition to the BX-size holes being drilled on the mine larger holes are used for hanging-cave work and in some cases for slot blasting. These holes were NX size, but as the largest explosive sticks available were only 2½ in. the latest holes are all 2¾ in. diam. All these are drilled with a standard BX pilot followed by a reamer, but some full-size noncoring crowns with the latest stone pattern (BX4) are now being manufactured for test purposes to determine which method is the more economical, see Fig. 6.

Early experiments proved that to prevent any discoloration due to heating the waterflow over an EX crown should be 4 gpm, and 6 gpm over a BX noncoring crown. However, with the introduction of more powerful machines, it was found that despite a flow in excess of these figures certain portions of the crown face were becoming discolored or damaged by heat. It was clear, therefore, that with the one hole crown, waterflow across the face was not sufficient, and tests were made, first by increasing water pressures and second by using specially made crowns.

These tests showed that there was little to be gained by increased pressure. Optimum results were obtained with water at 130 lb per sq in. Two-hole crowns gave greater and more even flow of water than the single-hole, and heating was not evident even when water pressure was dropped well below average. In a further test with crowns with two holes but with offset water grooves not connected to the water holes, see Fig. 7, sludging was excellent for the first few feet but fell away rapidly as chippings packed in spaces between the stones.

It is not clear from these tests that better sludging is to be obtained with two water holes and grooves in the crown face, and when the present series of tests is concluded it is intended that a major test will be run on the BX4 two-hole design.

The crown profile has been altered considerably over the years, but it has now been standardized with a 25° inner slope. It was found that with a more acutely angled or flatter face performances were poor and holes deviated. A deeper angle presented manufacturing difficulties.

Little work has been done recently on matrix materials. The tin bronze used exclusively in crowns supplied to this corporation apparently satisfies the requirements sought, resistance to abrasion by the sludge and ability to hold the diamonds securely.

As drilling experience has increased, the trend on the mine has been towards drilling larger blastholes to reduce diamond drill footages and development work required and at the same time to increase the operators' productivity. Consequently it has been necessary to find machines of suitable qualities for the heavier work. Eighty diamond drills, as well as 45 percussion machines, are now empolyed to break 350,000 tons monthly, whereas 320,000 tons were broken previously by 34 stopers.

Four main problems in machine design have to be considered: spindle speeds, power, types of feed, and the pressure on the diamond crown most suitable for any particular ground. Little work has been possible locally on the fourth problem.

The original machines used for EX drilling ran between 1600 and 1800 rpm, but slow speed drilling tests in South Africa were so successful that experiments were carried out here. These tests were made

with BX-size holes, and as it was found that rod vibration was noticeably less than at higher speeds and performances better, all new machines are designed to operate between 900 and 1250 rpm. It is of interest to note, however, that at 2500 rpm a standard EX noncoring crown gave a life of 435 ft as against the normal 111 ft and penetration was 60 pct faster, but owing to the excessive machine and equipment wear these tests were abandoned.

With the larger Q holes and the longer BX holes now being drilled, it was found that the machines on the mine were underpowered. Twenty-five 18-hp piston machines have now been introduced and are operating satisfactorily. A major advantage of these machines is that they are fully reversible, and with the new rods rod-changing is a matter of seconds.

Increased air consumption with these larger drills has now diverted attention to the possible advantage of drills with a different type of drive, and a certain amount of test work on an electrically driven hydraulic oil machine has been carried out in the test chamber. With the necessary oil tanks and pumps the drill was cumbersome, but results were so encouraging that a second prototype has been made.

This second machine incorporates an hydraulic feed system, and it is expected that the steady pressure on the crown will improve both crown life and drilling speed. All the present machines are fitted with automatic screwfeeds, as the hydraulic feed cylinders are both heavy and vulnerable to abuse.

How Diamond Drilling Influenced Mining at Rhokana

Considerable advances have been made in stoping layouts since diamond drills were first introduced. The original method was to drill EX fanning rings at 5-ft intervals along subdrives mined at 25 ft (later 50 ft) vertical intervals, Fig. 8, but when BX drilling was adopted parallel holes were drilled from crosscuts driven every 10 to 12 ft from the sublevel on the hanging wall side. The sublevel vertical interval was now increased to 70 ft, and the latest method of BX fan drilling from the hanging wall drive has eliminated some 150 ft of crosscut development for each stope. In this method, which is proving the most efficient to date, the BX split rings, Fig. 9, are drilled with 6-ft burdens, but in such a way that the holes in the second ring cover the spaces in the first ring. The toe-burden in each split ring is 24 ft.

Item	Parallel Ring	Split Fan Ring
* Footage drilled	1050	1087
* Footage charged	1002	795
* Cases explosives	37.11	29.44
Tons produced	6660	7910
Tons per foot drilled	6.34	7.28
Tons per case explosive	179	269

* Excluding any easer holes.

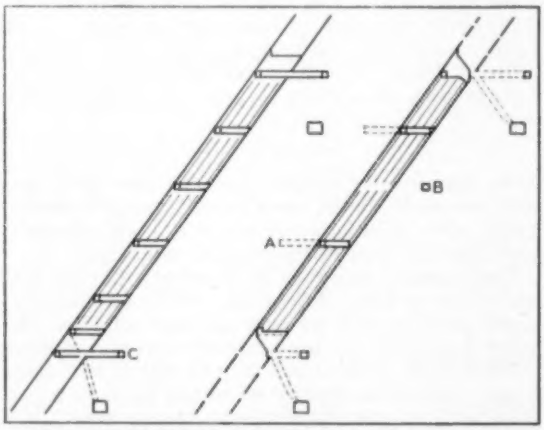


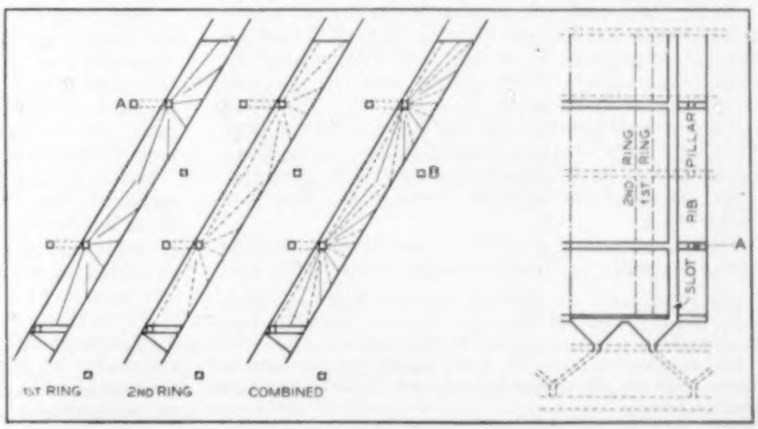
Fig. 8—At left, old method of parallel drilling from crosscuts on sublevels spaced at 50-ft intervals. At right, later method of parallel drilling from crosscuts on two levels only. *A*, crosscut for hanging wall caving; *B*, pillar recovery drive; *C*, grizzly level.

In each method, a slot is mined across the orebody from foot to hanging wall and the rings are blasted successively into this.

In the last 15 years, the use of long blastholes for rock-breaking has revolutionized the system of mining at Rhokana, and the tonnage produced per miner has been more than doubled. At the same time, it has been possible to evolve a mining method that is very much safer than the original shrinkage stoping system, as all work is now carried out from positions well clear of the open stopes.

In any system, however, the overall costs are of major importance, and with the high price of diamonds and the rising world prices of labor and material, the continued employment of diamond drills for long blasthole work at Rhokana has been made possible only by continuous research and test work. With the improved efficiency resulting from the experiments described, it is confidently expected that diamond drilling will play a major part in mining operations at Rhokana for many years to come.

Fig. 9—At left, split ring stoping cross-section shows method of drilling from hanging wall drives. *A* indicates hanging wall crosscut for caving. *B* indicates pillar recovery drive. At right, first and second rings of longitudinal stoping. *A* indicates hanging wall crosscut.



Colorado Fuel & Iron Corp.

Improvements in Plant and Operations At Pueblo Coal Washery

Making maximum possible use of available equipment and material, CF&I placed a high-efficiency, high-capacity washery unit in the existing buildings to gain simplified operation, reduced manpower requirements, raised efficiency, and boosted production.

by J. D. Price and W. M. Bertholf

THE central washing plant of the Colorado Fuel & Iron Corp. was first operated in 1918 to furnish coal for two 60-oven batteries of Koppers design. Prior to that time the coke for the blast furnaces had been secured from a number of beehive operations, some with their own washeries.

The original washery had four Elmore jigs, which did not do as well as had been expected. In 1923 the jigs were taken out and replaced by Deister Plat-O tables, with various changes in auxiliary equipment. In 1936 the throughput of the plant was considerably increased by the installation of vibrating filters for recovery and drying of fine coal, thereby reducing a large recirculating load of fine coal which passed through the screens of the Carpenter driers.

In the late 1940's it became evident that something would have to be done to keep the washery abreast of progress at Pueblo and other washeries. Coal requirements were nearly two and one-half times the original requirements of the 120 small ovens, as additional ovens had been built in 1930, 1938, and 1945, whereas no additional coal washing capacity had been added since the 1936 modifications. Much of the equipment, moreover, had seen better days.

One answer to the problem was to build a new and completely up-to-the-minute plant, with separate sections for coarse, medium fine, fine, and very fine coal. On the other hand, it might be financially more profitable to place a high-efficiency, high-capacity unit in the existing buildings.

The washing problem at Pueblo is not unique, but it is approached differently. There are no established specifications for coke ash and sulphur. The plant is operated on the principle that if it is more economical to wash it out than to slag it out, wash it out; otherwise, send it on to the blast furnaces. With coals at the Pueblo plant costing what they do, the benefits of washing at a low gravity are questionable. Hence the primary problem is to eliminate the high-ash components and retain all the low and medium-ash components. Sulphur is no problem at all, averaging 0.6 pct in the coke.

Since a good proportion of the free impurity in the coals is as large as the coal or bone or larger, it appeared that it would be safe to go to jig washing and discontinue crushing the coal before washing, as had been the practice with the tables. This would boost the throughput. It might also decrease manpower requirements and washing costs considerably.

It was assumed at the start and has been demonstrated in the first year of operation that a jig will do as well on the fines as the tables had been doing. It would not be necessary to discount any gains due to increased efficiency in washing the coarse material because of incapacity to wash the fines.

By washing at $-2+0$ mesh it would be possible to dewater, by screening, a considerable tonnage satisfactorily, for example, at $-2+\frac{3}{8}$ or $-2+\frac{1}{4}$, and then crush it in a hammer mill. The $-\frac{3}{8}+20$ could be dewatered in centrifugal driers and the remain-

J. D. PRICE and W. M. BERTHOLF, Members AIME, are, respectively, Superintendent and Preparation Engineer, By-Product Coke Plant, Colorado Fuel & Iron Corp., Pueblo, Colo.

Discussion on this paper, TP 3922F, may be sent (2 copies) to AIME before Feb. 28, 1955. Manuscript, Feb. 2, 1954. New York Meeting, February 1954.

ing fines handled as before in the old fine coal circuit until it was possible to work out something better, if that should prove necessary. The net result would be that 1—large rock would be rejected immediately and completely; 2—large coal would be dried very economically and then crushed in a machine designed for the job; 3—the medium-size coal would be dried in a few efficient units; and 4—even with increased throughput, the total quantity of fines to be handled would not strain existing facilities. If all went well, there would be a continuing saving as compared with the cost of operating the old plant, in addition to the fact that more coal would be washed than the present ovens could possibly carbonize, and there would be ample time for repairs and maintenance on down shifts.

Installation of the new equipment, originally planned for late fall 1951, was started early in 1952. By late May there were two jigs in place, and enough auxiliary equipment to operate after a fashion without interruption of coke plant operations. Because of the steel strike all operations were suspended for two months, and the contractor was relieved of the responsibility for completing the job. This took the company several months, and it was close to the end of the year before the installation was completed.

The data presented here are intended for comparison of results before and after the installation, with reasonable accuracy and in enough detail to show that expectations will probably be realized in full. Charts show yearly averages from 1930 through 1953 and monthly averages from August 1952 through December 1953. Particular attention is directed to the last six months of 1953 as compared to the previous year of operation of the new plant as well as the old plant record.

Rearrangement of Washery

Fig. 1 illustrates the essential nature of the changes made in the washer building. Twenty-three primary tables as well as four rewash tables located on a lower floor were replaced by two 84-in., 3-compartment, 6-cell air-operated Jeffrey jigs, with a proposed 32 pct increase in hourly throughout. The area above old tables 15, 16, and 17 has been utilized for a modern electrical control room and on lower levels there is a considerable increase in the amount of free space. Six old Carpenter-type driers were replaced by 3 CMI Model E driers, with a saving in floor space which has since been converted to a weld shop for the coke plant.

The old drainage conveyor for washed coal has been removed and the collecting sump for fine coal reduced in size. Some of the trench system has been covered over, greatly facilitating housekeeping. Resulting space will be used to good advantage in an extension or replacement of some of the fine coal recovery equipment. The old boiler coal and refuse pits, at first floor level, were filled and also covered.

The dewatering screens, 5x16-ft Allis-Chalmers Low Heads, now occupy space formerly taken up by tables and launders. Below and west of these units the rewash floor was extended to take the clean coal crushers, Jeffrey Flex-Tooth, 24x42-in. This is the only part of the building which appears to be crowded, but there is ample room for any necessary maintenance work.

The only addition to the building is a small blister on the east side, housing the blowers and feed

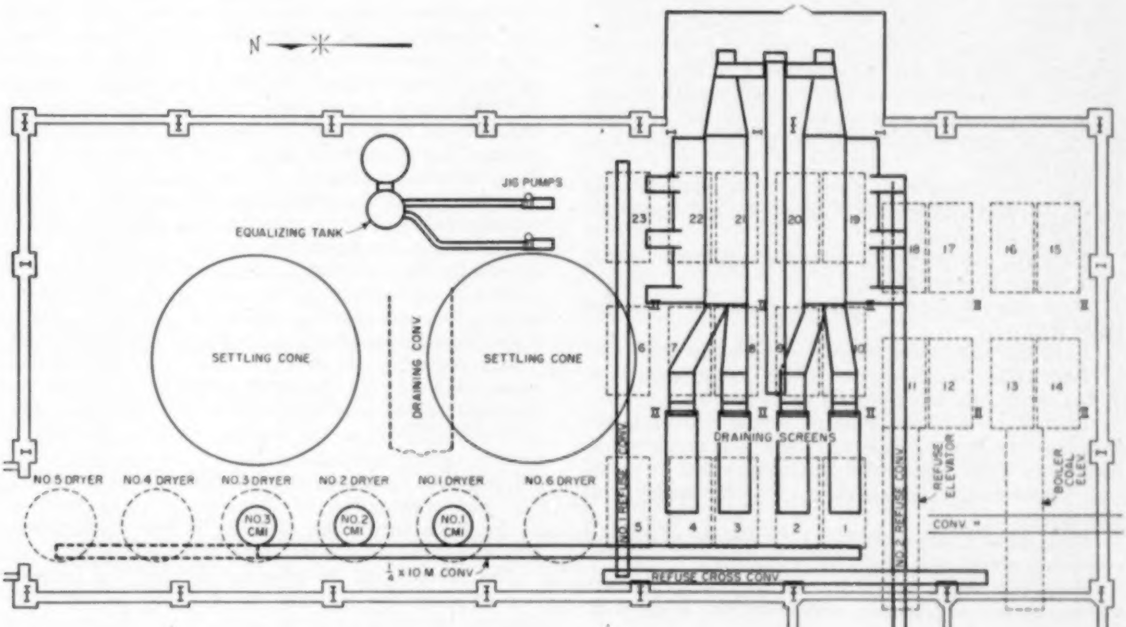


Fig. 1—In the washer building twenty-three primary tables and four rewash tables have been replaced by two 84-in., 3-compartment, 6-cell air-operated Jeffrey jigs. With the jigs coal is no longer crushed before washing as was the practice with the tables, since much of the free impurity in the coals is as large as the coal or bone, or larger. It has been demonstrated in the first year of operation that jigs can do as well on the fines as the tables were doing.

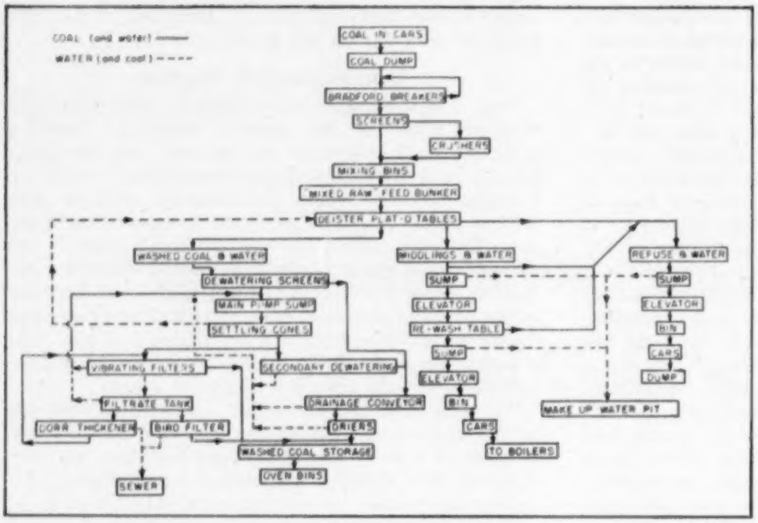


Fig. 2—This flowsheet of former operations should be compared with the new arrangements illustrated in Fig. 3. The Bradford breakers, the screens, and the roll crushers have now been eliminated, and coal is being dumped and sent directly from the receiving hopper to the appropriate bin.

sluices for the jigs. This has 19-ft clearance above the railroad tracks.

Building Schedule

The notations accompanying the contractor's* drawing shown in Fig. 1 were as follows:

"In general, the plant will operate at normal capacity during erection of Part I. While No. 1 jig (Parts II and III) is being erected, 14 tables will operate. After No. 1 jig is in operation the remaining tables will be removed and No. 2 jig will be erected (Part IV).

"Part Ia—Install three CMI driers. Remove one old drier at a time, install new ones, and operate with temporary chutes. With three driers in operation, remove remaining old driers and erect new platform with present distributing conveyor in operation. At a convenient time, remove present distributing conveyor and install ¼-in. by 10-mesh conveyor, removing No. 6 drier and supporting structure first.

"Part Ib—Erect new structure for blowers and jig chutes and sluices. Erect conveyor and conveyor gallery to jig sluices.

"Part IIa—In preparation for erecting No. 1 jig, alter water line to tables.

"Part IIb—Relocate present clean coal sluices from tables.

"Part IIc—Partition off raw coal surge bin.

"Part IIIa—Remove nine tables (numbered 3, 4, 5, 6, 7, 8, 21, 22, and 23) and erect No. 1 jig.

"Part IIIb—Remove present refuse elevator before erecting No. 1 refuse conveyor and cross refuse conveyor. (This required bypassing refuse to boiler coal pit and running all refuse up the boiler coal elevator.)

"Part IIIc—Erect part No. 1 of electrical control room necessary to operate No. 1 jig.

"Part IV—With No. 1 jig in operation, remove remaining old equipment, and erect No. 2 jig with remaining parts."

There were a few departures from this schedule, but in general the change-over was accomplished as planned. A comparison of the flowsheets before and after the change shows that the changes were not confined to washing machines; the whole system is involved. As of this date, no drastic changes have been made in the general operation of the fine coal system, but an investigation of more efficient operation of this part of the process is under way.

Raw Coal to Mixing Bins: The obvious change in this part of the circuit is the elimination of the Bradford breakers, screens, and roll crushers which served to reduce the 2x0 slack to approximately ⅜x0 for the tables. This has decreased the idle time at the coal dump, since it is no longer necessary to wait for the recirculating load of breaker reject to clear out between runs of different coals. The coal is now being dumped and sent directly from the receiving hopper to the appropriate bin.

During the first year operations were carried out with a mixture of a large number of coals. This was no change from the situation that had existed for 10 years, during which time it had been necessary to purchase outside coals to satisfy requirements. In mid-August 1953 it was possible through the opening of a new captive mine to eliminate the purchase of high volatile coking coal from outside mines. The mixture is much simpler now that only three mines are sending in coal of this kind.

It had become evident that the practice of using certain coals as interchangeable members of a group was causing irregularities in the feed that were automatically reflected in the product, and more accurate classification of the raw coals was anticipated. The situation is compared in Figs. 2 and 3. There is still room for improvement in mixing feed.

Mixed Raw Coal to Jigs: The raw coal bunker required for surge capacity between bins and individual tables was eliminated, and the feed now goes directly from the mixing bins to the jigs, a paddle switch controlling the air on the jigs. Any interruption of the feed automatically cuts off the air, and resumption of the feed restores the air. There is no surge bin, as such, in the present system; the mixing bins, in effect, serve a dual purpose.

The present set-up permits varying the proportion of total feed between the two jigs in any ratio desired, but to change the total feed it is necessary to go back to the mixing bins and readjust all the bin gate settings.

Since the composition of the mixed raw coal is determined by the proportion drawn from each bin, and the quantity is determined by the total gate opening,** any changes in composition or rate re-

* Contractor was the Roberts and Schaefer Co. of Chicago.

** The belts operate at constant speed.

quire that all bin gates be adjusted properly. Evidently it would have been wise at least to provide for variable speed operation of the mixing belts, with remote control from the jig floor. This would have permitted varying the load at will but retaining the desired composition.

Washing: The change in this section is so obvious as to require little explanation. Operation-wise the gain is tremendous. Flows of coal and water are much larger than formerly and far less liable to obstruction. Operation controls are centralized and it is possible to see at a glance whether or not a particular motor is still running. Weightometers indicate the input and output of the plant, and lights indicate whether or not there is a load on the mixing belts. Ammeters tell the story of load conditions at the crushers and driers, and interlocks prevent a major pile-up in case a machine fails.

Control of quality of product is simplified in many ways, as there are fewer units to watch and keep in proper adjustment.

Dewatering: All coal discharges from the jigs to flumes provided with 4x5-ft sections of ¾-mm wedge wire screen, serving as primary dewaterers. Semidewatered coal discharges to the top decks of the four Low Heads, fitted with either ⅜-in. or ¼-in. square mesh as the occasion demands. Oversize is discharged at a tolerable moisture content to the two 42x24-in. Jeffrey Flex-Tooth crushers and thence to the washed coal belt. Undersize from the top deck passes to the lower deck of 48-m equivalent wedge wire, and oversize is taken to the centrifugal driers by drag conveyor. After drying it discharges on the clean coal belt.

Undersize and water from the preliminary dewatering screens and lower decks of the Low Heads passes into two 10x0-m sumps from which it is pumped to the settling cones.

This system has one very important advantage over the old. It is virtually impossible for any wood chips, sticks, or pieces of coke to remain in the circulating water, and cleaning the screens at the equalizing tanks is now a thing of the past. It may seem unusual to include pieces of coke as unwanted flotsam in a washery water circuit, but on occasion it is necessary to pick up *hot coal* from storage, and some of this is already coked before it can be washed. It is, perhaps, superfluous to mention that when a high percentage of reload coal is used conditions are not what they are without it.

Another interesting point is that for the first time it is possible to get the washed coal too dry, in that capacity is lost at the ovens if all coal is dried as much as possible. There also appears to be a tendency for *dry coal* to cause excessive carbon deposits in the ovens. Experience at the Rosita plant of the American Smelting and Refining Co. at Chihuahua, Mexico, also indicated that this treatment of washed coal could result in its being too dry. The solution to this problem is to bypass some of the material from the lower deck of a Low Head around the driers.

Crushing: The new flowsheet, Fig. 3, provides for crushing the coal after it is washed. It was intended that pulverization of washed coal under the old system be matched by crushing of +¼-in. material after dewatering. Current operations indicate that it will be possible to maintain between 70 and 75 pct −⅛-in., with only a small amount of +½-in., in the total washed coal.

Fine Coal Recovery: On the surface this section appears to have been left unchanged. Fine coal and water are still pumped to the settling cones, settled solids are taken to the vibrating filters, a certain tonnage of fine coal is recovered as vibrator cake, and the remainder of the coal and water is recirculated. However, there have been changes in size and quantities of solids, as well as general closing up of the system, and studies are in process to determine what revisions of method or equipment are required to bring this section into line with the rest of the operation.

At the time the new washery was being planned a decision on what to do about fine coal and recirculating water was purposely delayed. It was believed that by the time the rest of the plant was operating at or near ultimate capacity it would be possible to make a much better estimate of requirements. This now appears to have been even wiser than was originally thought. Owing in large part to mechanized control of the water level in the cones and pump sump, losses of fine coal are considerably lower than formerly. The only losses are very fine high ash solids in overflow from the Dorr thickener and effluent from the Bird polisher, which operates on thickener underflow.

Refuse: Refuse had been hauled away in railroad cars for many years, but the increased traffic around the washery after the 2000 tons per shift was passed necessitated haulage by truck. This change has resulted in a saving of direct labor at the washery, since the driver loads his own truck, and the charge for the trucking is much less than the previous railroad charges.

Washed Coal: No change was made in the washed coal conveyor, except to install a weightometer and

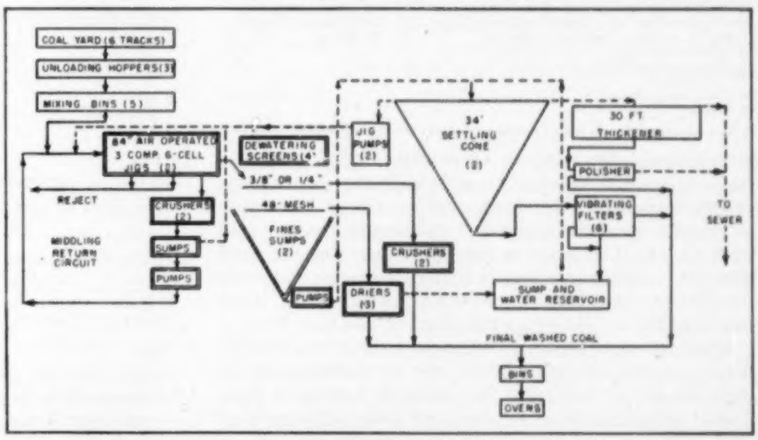


Fig. 3—In this latest flowsheet the machines in double lines are new. Dotted lines represent flow of water or thin slurries. Solid lines represent flow of coal or other solids or sludges.

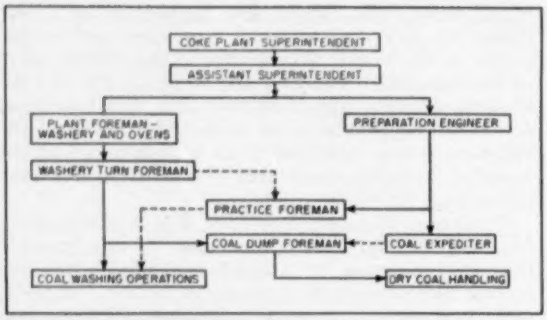


Fig. 4—Manpower requirements shown here should be compared with those in Table I.

put the starting switch on the central control panel. An indicating light shows whether clean coal is going to the main storage bin or is being bypassed direct to the oven bins.

Overall Operation: It should be evident that plant operation is now a great deal simpler than before the change. A multitude of small units operating in parallel have been eliminated, and controls for the entire plant have been consolidated.

On the other hand, there is more danger of losing a large percentage of throughput in case of a breakdown at the jigs. In an emergency, however, one jig can handle as much coal as the old table plant operating at full capacity.

Labor Requirements

Fig. 4 indicates the reduction of manpower required per operating shift. Since output has increased from about 1650 tons per shift to about 2650 tons, manhours of labor are half the previous figure. Fig. 4 illustrates the flow of authority from top level to operating force. Solid lines indicate direct supervision and dotted lines functional supervision. At the time this reorganization was effected, certain

Table I. Promotional Line at Pueblo Coal Washery Before and After Reorganization

March 1949		March 1953
Group A	**Group B**	
1 Table operator	1 Head coal unloader	1 Coal expediter
2 Vibrator attendant	2 Car spotter	2 Jig attendant
3 Handyman	3 Car spotter helper	3 Fine coal man
4 Assistant table operator	4 Coal unloader helper	4 Handyman (coal unloader)
5 Washed coal conveyor man		5 Washery oiler
6 Crusherman		6 Conveyor man
7 Oiler		7 K&X conveyor man
8 Drierman	**Group C**	8 Mixing bin man
9 Water tender	1 Table repairman	9 Washery helper
10 Tripper man	2 Table repairman helper	10 Cleanup helper
11 K&X conveyor man		11 Labor
12 Mixing bin man		
13 Crusher operator helper		
14 Cleanup helper		
15 Labor		

government regulations interfered with plans to make the coal expediter a company man on salary, whose experience in this position would train him to become practice foreman. Consequently the coal expediter is top man in the operating line-up, and present incumbents were selected from the seniority list after a considerable period of weeding out those not capable of handling the job.

Weekly or oftener, if necessary, the coal expediter prepares detailed schedules for each operating shift, based on need for the various coals and estimated availability as determined from schedules of operations at the mines and records of shipment and receipt of individual cars.

The practice foreman, in charge of the actual washing operation, is primarily concerned with quality of product. Since quality cannot be maintained unless operations are smooth and continuous, he is interested in the condition of the machinery and makes frequent inspection tours. He is responsible for making the necessary adjustments in air pressure, water, and float counterweights to suit the mixture being washed and keeps a log book in which he reports operating conditions and difficulties. Control of the mixture over longer and longer periods of time has contributed materially to the improvement of operations.

Table I indicates streamlining of the operating force before and after the reduction in manpower.

Washery maintenance is handled by the mechanical department of the steelworks. There are three teams of millwrights and helpers, one for the fine coal system, one for the remainder of the washery, and one in the dry coal handling system. It is too early to state that repair and maintenance is either more or less expensive than formerly. The cost sheets, when interpreted by one familiar with the changes made in the flowsheet, indicate that after a time reduction in these costs may well be expected.

At the start there was considerable trouble with the pumps, but after installation of a separate high-pressure line for gland water there has been much less difficulty.

The air intake for the jig blowers is located on the side of the washery next the coke ovens. Fine coke dust appeared to be causing trouble in the air valves. This was remedied by installation of large oil bath air cleaners.

Live steam is available for cleaning the float mechanisms at the main jig floor level and the ejector mechanisms at the lower jig floor level. Cleaning and inspection have been facilitated by placing windows of 2-in. mesh welded wire fabric in some of the guards. This fabric has also been used to guard the tops of drag conveyors.

Except as used for sample preparation, hammermills are new to the staff. The first difficulties with these machines were due to poor design of the discharge chutes, which tapered in from all four sides, causing clogging of the mill from the bottom. Now the chutes have been altered this no longer occurs.

The present centrifugal driers are requiring less manpower for maintenance than the old driers, and

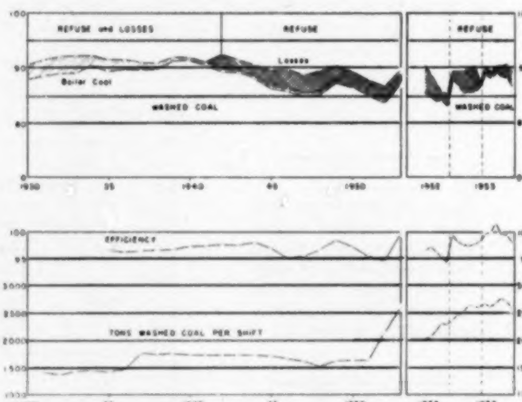


Fig. 5—Yields, efficiency, and throughput. Probably no attempt will be made to increase hourly tonnage, as auxiliary equipment is nearing the point of diminishing returns.

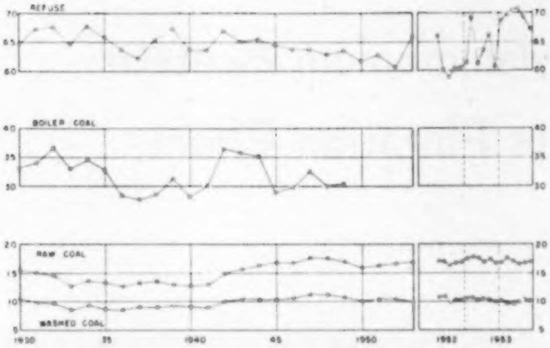


Fig. 6—Percent ash, raw coal, and products. Boiler coal is no longer used, but comparative statistics are of interest.

a much smaller unit handles as much material or more. It was necessary to take drastic steps in handling the fine coal. Some of the settling cone underflow has been put in the driers whenever the circulating water has been too heavy. It has been demonstrated that these driers can handle this type of material, but it is not at all certain that they should be expected to do it indefinitely. The addition of this type of material to the normal feed results in excessive fluctuations in the load at the motor, which probably is a very mild reflection of the strains on the internal gearing. Apparently there is a lower limit to the size of material which should be fed these machines if long, trouble-free life is expected from them.

Comparative Statistics

Statistics of these endeavors have justified most of the expectations for the new plant. Figs. 5 and 6 illustrate in part the extent of improvement to date. To illustrate the general trend from 1930 to 1953 yearly averages are given, inclusive of all items. On the extreme right of each chart a panel shows monthly averages from August 1952 through December 1953. Predictions are based on the assumption that the mixture can be controlled as well in the future as in the last six months.

Fig. 5. Tonnage, Efficiency, and Yields: Throughput per 8-hr shift has definitely been boosted, reaching a new high in efficiency and minimizing losses. It is unlikely that an attempt will be made to increase hourly tonnage appreciably, for indications are that all auxiliary equipment is nearing the point of diminishing returns. Probably the jigs themselves could handle a considerable increase in tonnage if they were not held back by the rest of the equipment, for one jig will do good work on a load considerably greater than half the total now fed to two jigs operating simultaneously.

Although efficiency cannot be boosted very much, it will be maintained at the current level, or slightly better.

$$\text{Efficiency} = \frac{100 \text{ x tons } \textit{dry} \text{ washed coal}}{\text{tons } \textit{dry float in feed} \text{ at W.C. ash}}$$

Losses indicated on the chart are 1—moisture loss and 2—loss unaccounted for. Moisture loss usually amounts to between 1.0 and 1.5 pct and is due to correction of washed coal to 2.5 pct moisture; raw coal contains 3.5 to 4.0 pct moisture. Losses unaccounted for may or may not be entirely real, since they are actually a balancing figure and on occasion have been negative.

Fig. 6. Ash Content of Raw Coal and Products: Since 1950 raw coal ash appears to have increased slightly, but in the past 18 months washed coal ash has been maintained at the same level.

Boiler coal is now a thing of the past, and this data is included merely as a matter of interest. Note that it was possible to get by with a fairly high ash content for three years, 1942 through 1944, but the power department later refused to burn solid fuels.

Refuse ash had gradually declined over almost the entire period since 1930. This is largely explained by the fact that an attempt was being made to keep the washed coal ash from going up as rapidly as the raw coal ash. Chart fluctuations for refuse ash in the last 18 months can be attributed partly to conditions of which the operating personnel were unaware and partly to inexperience.

The major problem is common to all wet washing plants: control of circulating water density and complete recovery of fine coal. Eventually this will be complicated by the necessity for keeping even the undesirable fines out of the streams. Since there is a large amount of semicolloidal clay in the water this may become a big difficulty, for it is not possible to operate on a closed water circuit for more than a few hours at a time. It would be disheartening to have to remove clay from water, at considerable expense, and then haul it away.

Better results are achieved with *thin* water, that is, the specific gravity should not be allowed to go above 1.04 to 1.05 and probably should be 1.03 to 1.04. It is certain that densities higher than 1.05 are not desirable and around 1.08 are impossible.

The mechanization of water tending and reduction of the amount of water in circulation have helped considerably, but simple gravity settling of the fine coal in the present settling cones does not appear to be sufficiently rapid to accomplish what is necessary. Total area of the settling cones is about 1800 sq ft, and these were installed for use in a plant with approximately half the present capacity. The original design was good, for there is no difficulty at all if only one jig is used.

Experiments with a large cyclone thickener are now under way. It is hoped that the cyclone will thicken the vibrator to the point where it will not be necessary to maintain an overflow there. If this can be done, there will be an appreciable reduction in the circulation of water through the cones, and if this is great enough it may be possible to maintain the desired specific gravity of the circulating water without undue expense.

When water and coal mixture problems are under control simultaneously serious consideration can then be given minor problems such as determining the proper air valve settings, the proportions of *over* and *under* water, and the number of pulsations per minute.

Summary

Certain goals have been reached. Washed coal of acceptable quality is being produced with greater efficiency than ever before and with about half the labor per ton. Control of coal supply has been brought to the point where the plant can operate on a much more stable mixture and with lower railroad charges for demurrage, both of which contribute materially to reducing washing costs. Once the fine coal problem is under control, techniques can be refined to the point where everything possible is being achieved with the available material and equipment.

Adsorption of Dodecylammonium Acetate On Hematite and Its Flotation Effect

by A. M. Gaudin and J. G. Morrow

FLOTATION requires the existence of a definite contact angle. This contact angle, the surface tension of the solution, and adsorption at the solid-fluid interface are quantitatively related.

Adsorption of dodecylammonium acetate on hematite was measured for a wide range of concentrations of reagent in solution. Similar measurements for quartz have already been made.[1] Contact angle measurements were then made on polished surfaces of hematite and of quartz immersed in aqueous dodecylammonium acetate solutions, and a functional relationship was sought between adsorption density at the mineral-solution interface and the contact angle. Finally, the surface tension of the aqueous amine acetate solutions was measured. These data were combined to give an evaluation of the work of adhesion for the three-phase system.

Specular hematite was crushed and then ground dry in a laboratory porcelain mill, with flint pebbles, to pass a 200-mesh screen. The ground product was sized in a Haultain infrasizer, and one of the granular sizes (cone No. 3) was used in all adsorption tests. A hand magnet was used to remove magnetite and abraded iron. Quartz was removed in a Frantz isodynamic magnetic separator. The purified hematite was leached in aqua regia, washed with distilled water until the washings appeared free of electrolyte by conductance measurement, dried in a low-temperature oven, and stored in a pyrex container.

The specific surface of the closely sized hematite was determined by the krypton gas adsorption method.[2] Three measurements gave an average value of 1350 sq cm per g. Chemical analysis showed Fe = 69.37 pct, insol = 0.72 pct.

The quartz used in the flotation tests had been prepared by Chang[3] for an earlier investigation.

Demineralized distilled water was used for all test solutions. Dissolved salt content was of the order of 0.03 ppm, expressed in terms of sodium chloride, as estimated from conductance measurements.

Dodecylammonium acetate was obtained from Armour & Co.[4] in two forms, the unmarked compound and a preparation marked by carbon 14 in the hydrocarbon chain of the aminium ion. Specific activity of the active salt was 0.134 millicurie per g.

The important physico-chemical constants for the primary amine salt have been reviewed by de Bruyn.[1] The calculated effect of hydrolysis of amine salt on pH of aqueous solutions and the effect of pH on the distribution ratio of the alkylammonium ion to free amine are of particular interest.

All other chemicals used in this investigation were of analytical reagent grade. A *column method*[1] was used for adsorption work.

Attainment of equilibrium distribution in the adsorption column depends on the solid-solution contact time, hence upon the volume of solution passed. It was assumed that contact time required for equilibrium would be a maximum for the lowest reagent concentrations. On this premise it was demonstrated experimentally that the passage of 500 ml of solution through the mineral bed was adequate.

An aliquot (1 to 5 cc) of the solution to be analyzed was transferred to a small pyrex cup and allowed to evaporate to dryness at room temperature; 4 or 5 mg of unmarked amine acetate were added to the dried sample and the cup and its contents were transferred to the combustion system for analysis. Evaporation at room temperature must be emphasized, as even slightly elevated temperatures result in loss of reagent. A laboratory model G Beckman pH meter equipped with a glass electrode was used to measure pH of amine acetate solutions.

The technique of internal gas counting of radioactive carbon dioxide in a Geiger-Muller counter was used. Developed originally by Brown and Miller,[5] this method was adapted to the analysis of carbon-14 marked flotation reagents by Chang, de Bruyn, and Bloecher.[6] Analytical method and procedures have been described in detail by Bloecher.[7]

Contact angles were measured by the captive-bubble technique.[8] The mineral specimens were carefully selected to avoid cracks and inclusions of other minerals. All specimens were mounted in plastic and polished to produce a smooth surface. The final polishing and contact-angle measuring

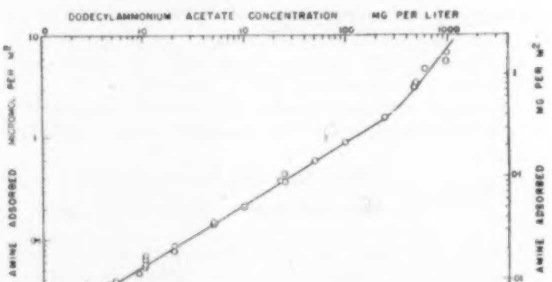


Fig. 1—Adsorption of dodecylammonium acetate on hematite as a function of concentration.

A. M. GAUDIN, Member AIME, is Professor of Mineral Engineering, Massachusetts Institute of Technology. J. G. MORROW, Student Associate AIME, is Research Metallurgist, Freeport Sulphur Co., Freeport, Tex.

Discussion on this paper, TP 3932B, may be sent (2 copies) to AIME before Feb. 28, 1955.

Manuscript, April 8, 1954. Abstracted from the thesis by J. G. Morrow submitted in partial fulfillment of the requirements for the degree of Doctor of Science at Massachusetts Institute of Technology. Chicago Meeting, February 1955.

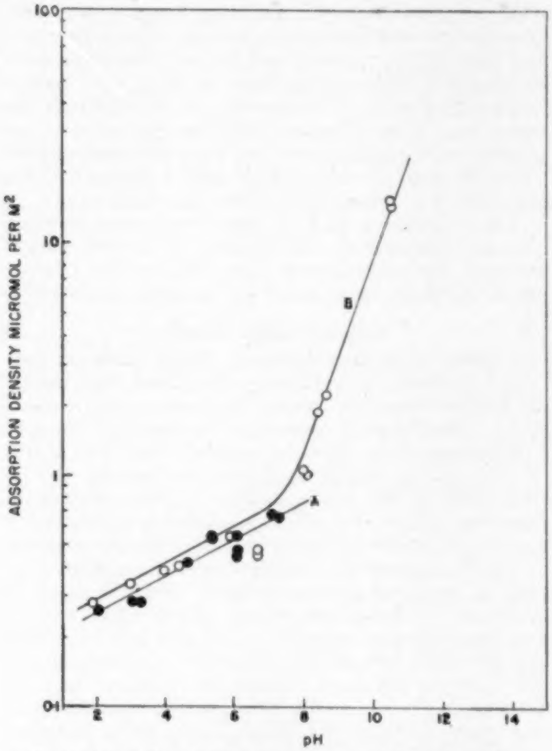


Fig. 2—Adsorption of dodecylammonuim acetate on hematite (*A*) and quartz (*B*) as a function of pH. (Data for quartz according to unpublished data by de Bruyn.)

techniques described by del Guidice[9] were used. Conditioning of the polished surfaces in amine solution was done in the optical-glass cell with a mechanical stirrer. The conditioning time was ascertained by trial to give the maximum angle at each concentration.

A Cenco-duNouy tensiometer was used to measure the surface tension of aqueous solutions of dodecylammonium acetate at 25°C. The concentration of dodecylammonium acetate required to induce incipient flotation of hematite and quartz was determined by the vacuum-flotation technique of Schuhmann and Prakash.[10]

Adsorption Results

The Adsorption Isotherm: The amount of agent adsorbed on hematite per unit area of solid (Γ) from aqueous solutions of dodecylammonium acetate was measured at concentrations ranging from 0.8 to 4080 micromol per liter. Results are given in Fig. 1, in which log Γ is plotted against log c. Adsorption is expressed in milligrams per m², or in micromols per m², the latter being numerically equal to gibbs.[11] Minor variations in temperature occurred during the tests so that reference to Fig. 1 as an *isotherm* is not rigorously correct. All pH readings (5.8 to 6.6) indicated slight acidity. A trend toward higher pH values was noticeable with increasing concentrations of the agent.

Fig. 1 shows that adsorption density increases with increasing concentration. Over the concentration range from 0.8 to about 1000 micromol per liter log Γ is proportional to 0.6 log c. This means that Γ increases approximately as $c^{0.6}$. At higher concentrations Γ increases more rapidly with c. The bend in the isotherm at about 1000 micromol per liter occurs at a surface coverage about one quarter of a complete monolayer. The area required per ion adsorbed was assumed to correspond to two oxygen sites, or 24.08 A² of surface.[16, 18] It is assumed further that the adsorbate attaches itself to the mineral surface through its polar end with the hydrocarbon chain oriented perpendicular to the mineral surface. On these premises a monolayer will be obtained for an adsorption density of 6.90 gibbs.

Effect of pH on Adsorption Density: The adsorbate concentration in the test solution was maintained at approximately 100 micromol per liter (25 mg per liter) while the pH was varied from 2.1 to 7.2 with HCl or NaOH. Adsorption tests made in more alkaline solutions were discarded because the solutions became turbid. Results obtained are presented in Fig. 2. A variation in pH on the acid side of neutrality has only a small effect on adsorption density. In fact, for a ten thousandfold change in hydrogen ion concentration the corresponding change in Γ is only twofold. The effect of pH on the adsorption of amine on quartz[1] (40 micromols per liter) is also shown in Fig. 2. Here adsorption varies only slightly with pH in acid solutions but increases rapidly in alkaline solutions.

It was experimentally ascertained that the adsorption density is independent of the specific surface of the hematite.

Reversibility of Adsorption and of Desorption: A series of 10 tests was made to determine the exchangeability between adsorbed agent and agent in solution. Hematite was first coated with inactive dodecylammonium acetate by passing 500 ml of amine salt solution through the mineral column. Subsequently a known volume of radioactive amine acetate solution of the same concentration was passed through the pre-coated mineral bed. The observed adsorption determined by radio-assay represented the amount of radioactive amine from solution that had exchanged with unmarked agent

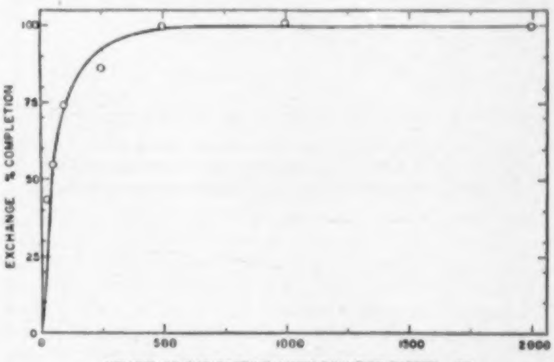


Fig. 3—Reversibility of adsorption of dodecylammonium acetate on hematite. Radioactively marked agent replaces the inert agent.

adsorbed at the mineral surface during the precoating treatment. The adsorption expected for complete exchange was determined from two tests in which only the active amine solution was passed.

Results are shown in Fig. 3. Complete exchange between the unmarked and radioactive amine occurred when volumes of 500 ml or more of the radioactive amine solution were passed through the pre-coated mineral bed. Under conditions prevailing in these tests the passing of smaller volumes was inadequate for complete exchange.

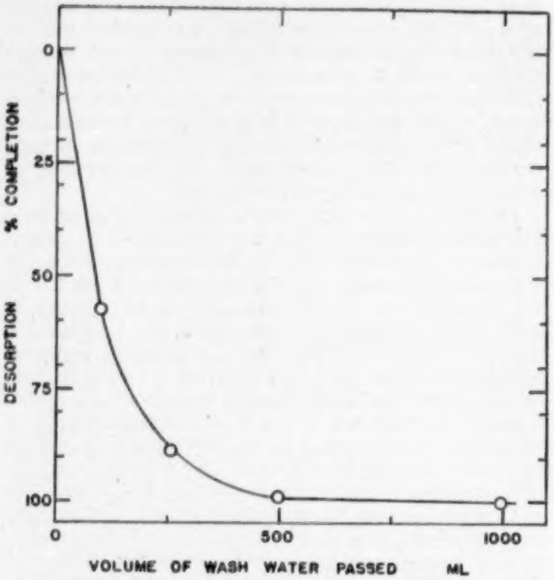


Fig. 4—Reversibility of adsorption of dodecylammonium acetate on hematite. Water leaching of adsorbed marked agent.

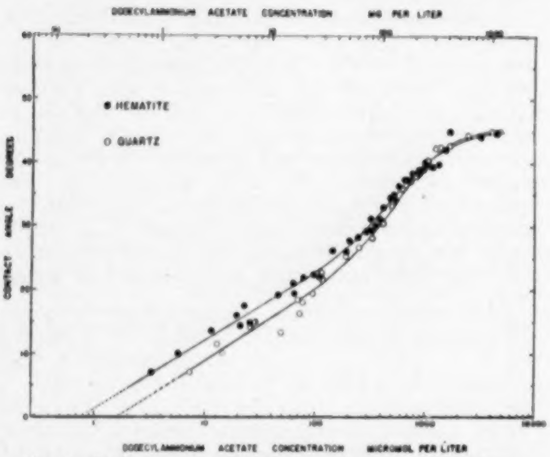


Fig. 5—Contact angle on hematite and quartz in solutions of dodecylammonium acetate as a function of concentration.

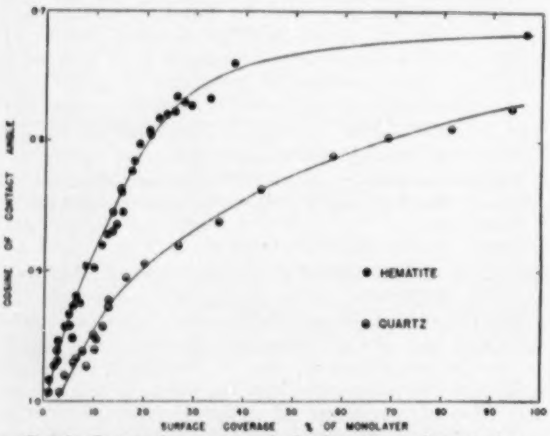


Fig. 6—Cosine of contact angle for hematite and quartz in solutions of dodecylammonium acetate as a function of the surface coverage of the solid surface by the adsorbed agent. Constant pH conditions.

In another series of tests the mineral was first pre-coated with radioactive amine acetate by passing through the mineral bed 500 ml of solution containing 204 micromol per liter of the agent. Then a measured volume of water was passed through the same bed. The difference between the equilibrium amount of adsorption and the amount remaining on the solid after the water wash gave a measure of the desorption or leachability of the adsorbed amine.

Fig. 4 shows a plot of desorption, expressed as percent completion, vs volume of water passed through the mineral bed. It is obvious that the reagent is readily washed off the mineral surface.

Contact Angle Results

Contact angle measurements were made on polished surfaces of both polycrystalline and monocrystalline hematite in aqueous amine acetate solutions. Conditions of essentially constant pH (6 to 7) and temperature were maintained. Fig. 5 is a plot of the contact angle, expressed in degress, vs the logarithm of the concentration of amine acetate in solution. Fig. 6 shows the relationship between the cosine of the contact angle and the surface coverage.

Fig. 5 suggests that a measurable adsorption density is required before a finite contact angle is obtained. The angle increases slowly with increasing concentration until at 1 millimol per liter (250 mg per liter) of agent in solution a contact angle of 38° to 40° is obtained. Further increases in the concentration have a small effect on the magnitude of the angle, whereas the adsorption density increases rapidly, see Fig. 1. An apparent maximum angle of 45° is indicated. In terms of the surface coverage it is interesting to note that 20 to 25 pct surface coverage gives an angle of about 38°, while at nearly complete coverage the contact angle is only 45°. It will be recalled that the bend in the adsorption isotherm (Fig. 1) occurred at approximately 25 pct surface coverage.

A number of measurements were made in which the polished surface was conditioned in the amine acetate solution and then transferred to a bubble cell. The contact angle was then measured in water. In each case the contact angle diminished to such a small value it could not be measured. This is not surprising in the light of the data that have already been presented showing the ease with which the adsorbate can be washed off the mineral surface.

Measurements of contact angles on polished surfaces of quartz are also included in Figs. 5 and 6. For Fig. 6 de Bruyn's[1] data on quartz adsorption were used. Fig. 5 indicates that the contact angle on quartz increases with increasing concentration in about the same way as the angle increases in hematite. At low concentrations the angle on hematite is somewhat larger than the angle on quartz for any given concentration. This difference diminishes with increasing concentration. Here, also, a maximum angle of 45° is indicated. At approximately 280 micromol per liter (70 mg per liter), the concentration corresponding to the bend in de Bruyn's adsorption isotherm on quartz, the contact angle is about 28°. The amount of amine acetate adsorbed at 280 micromol per liter (70 mg per liter) is 22 pct of that required to form a monolayer.

Quartz surfaces conditioned in amine solutions and then transferred to the bubble cell filled with water exhibited only cling angles after a short conditioning period.

Effect of pH on the Contact Angles of Hematite and Quartz at Constant Concentrations of Amine

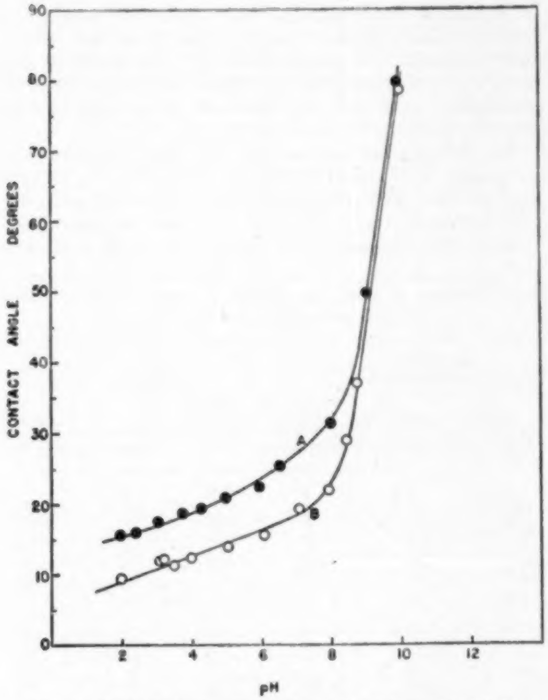


Fig. 7—Contact angle on hematite (*A*) and quartz (*B*) in solutions of dodecylammonium acetate (102 and 40.8 micromol per liter, respectively) as a function of pH.

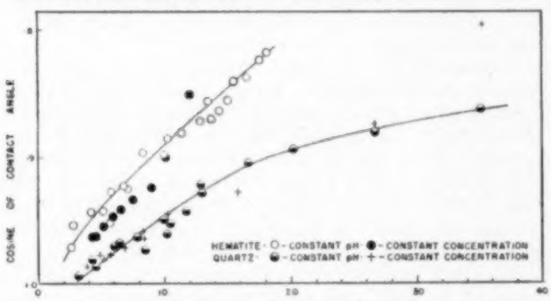


Fig. 8—Cosine of contact angle for hematite and quartz in solutions of dodecylammonium acetate as a function of surface coverage. Constant pH or constant concentration of agent in solution.

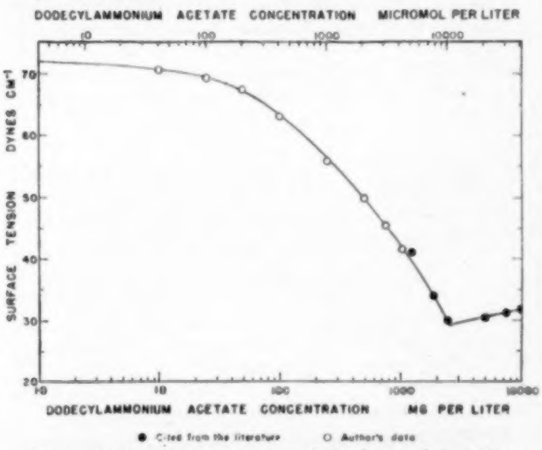


Fig. 9—Surface tension of aqueous dodecylammonium acetate solutions, in function of concentration.

Acetate in Solution: Contact angles were measured on polished surfaces of hematite and quartz in aqueous amine acetate solutions in which the concentration of the salt was maintained constant while the pH was varied from 2 to 10. Concentrations of 102 and 40.8 micromol per liter were used for hematite and quartz respectively. The pH was regulated with hydrochloric acid or sodium hydroxide.

Fig. 7 is a plot of contact angle vs pH. The angle increases slowly with increasing pH up to a pH value of about 8. Thereafter even a slight increase in pH results in a large increase in the contact angle.

In Fig. 8 the coordinates are the same as in Fig. 6, that is, the cosine of the contact angle is plotted against percent surface coverage. In this figure data for each mineral are given in terms of measurements made at substantially constant pH and variable concentration on one hand, or at variable pH and constant concentration on the other. It seems that within the range covered by Fig. 8 the contact angle is related principally to the adsorption density rather than to the concentration of the pH.

Surface tension data for aqueous amine acetate solutions (pH near 6) measured at various concentrations and at room temperature, 25°C, using the ring method are presented graphically in Fig. 9. Solid circles show values from the literature.

Fig. 9, a plot of surface tension vs the logarithm of the concentration of amine acetate in solution, is a typical surface tension-concentration curve. It shows at first only a gradual decrease in surface tension with increasing concentration, then a more rapid decrease until a minimum value is reached. Thereafter, a slight increase is observed with increasing concentration. The minimum value of the surface tension is about 30 dynes cm^{-1} and occurs at a concentration of 1.2×10^{-3} mols per liter, essentially that of the critical micelle concentration (1.42×10^{-3} mols per liter).[36]

The work of adhesion of an air bubble to a particle may be given by

$$W = \gamma_{LA} (1 - \cos \theta) \qquad [1]$$

in which γ_{LA} is the surface tension of the liquid and θ the contact angle.[37]

Fig. 10 shows the calculated values of *W* plotted against Γ for hematite and quartz. Each curve shows *W* to increase and pass through a very flat maximum. Thereafter *W* appears to decrease slightly with increasing surface coverage. The maximum values for hematite and quartz are 13.5 and 13 erg per cm^2 respectively and occur at surface coverages of about 0.35 and 1.05 parts of a monolayer respectively. The values of *W* corresponding to the conditions necessary for good flotation of hematite and quartz, namely, 4 to 5 pct surface coverage, are of the order of 2.5 and 5 erg per cm^2 respectively.

The maxima in these curves are not well defined. Quite possibly the curves are more nearly horizontal to the right of the so-called maxima. Additional measurements of higher precision are required.

Energy of Adsorption: Eq. 1 may be regarded as an expression of the total work of adhesion corresponding to a given adsorption density, Γ. Therefore the increment, *X*, in the work of adhesion, for unit change in Γ is given by

$$X = \frac{dW}{d\Gamma} = \frac{d[\gamma(1 - \cos\theta)]}{d\Gamma} \qquad [2]$$

This quantity is the slope of the curve relating work of adhesion to adsorption density, that is, the slope

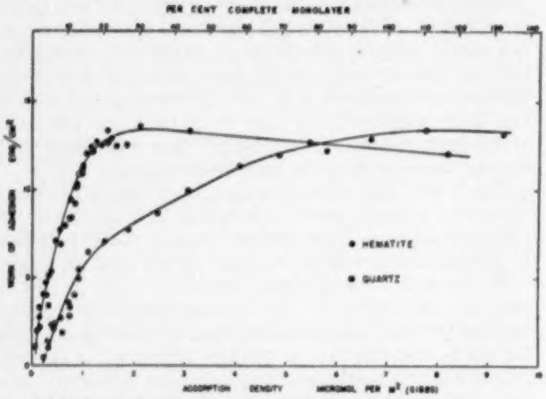


Fig. 10—Work of adhesion of hematite and quartz to air from aqueous solutions of dodecylammonium acetate, in function of surface coverage.

of the curves in Fig. 10. X may be thought of as the energy of adsorption of the latest adsorbate to be adsorbed.

Typical values of X for various values of Γ are given in Table I. For small surface coverages X is quite large. With increasing surface coverage, however, X decreases and actually changes in sign at high adsorption densities.

If the first ions to be adsorbed occupy the most active sites on the surface and are randomly situated, and if subsequently adsorbed ions occupy less and less active sites and remain independent of their neighbors on the surface, then the change expected in adsorption energy with changing adsorption density should be similar to that shown in Table I. The last ions that could be adsorbed and still remain independent of their neighbors would not be expected to have a large energy of adsorption. Hence the occurrence of low values for X at high concentrations is not surprising. However, a negative value for X is difficult to rationalize.

Correlation of Results and Interpretation

The authors' adsorption isotherm for hematite, see Fig. 1, and de Bruyn's isotherm for quartz[1] are remarkably similar. Adsorption densities (Γ) increase with increasing concentration (c) at low reagent concentrations. Similar breaks occur at intermediate concentrations. At high concentrations Γ increases more rapidly than c.

At low concentrations the log Γ-log c curve approaches a straight line of slope 0.5 in the case of quartz and 0.6 in the case of hematite.

Empirically it is possible to find the parameters for an equation

$$\Gamma = Ac^{0.5} + Bc \qquad [3]$$

which fits the data for hematite over the entire range studied. Such a curve is shown in Fig. 11, together with the experimental points. The values of A and B in Eq. 3 are 2.02×10^{-9} and 1.45×10^{-7} respectively.

This empirical result was found by assuming that the Bc term may be neglected in comparison with the $Ac^{0.5}$ term for the lowest experimental concentration ($c_1 = 2.45 \times 10^{-7}$ mol per liter) and by testing various B values until a satisfactory fit was obtained.

It is clear that the curves of Fig. 9 and Fig. 1 are alternative ways of presenting the data. In Fig. 1 two mechanisms are involved of which one appears at a higher concentration only, while in Fig. 11 a twofold mechanism is implied as occurring across the concentration range studied. The authors are unable to choose between these interpretations of the data, but it may be profitable to discuss briefly the implications of these diagrams.

De Bruyn concluded from his study of the adsorption of dodecylammonium acetate on quartz that neither a stoichiometric ion-exchange mechanism between the hydrogen ion and the aminium ion nor the adsorption of free amine is in harmony with experimental results. He favored an ionic adsorption process involving formation of an electrical double layer at the surface.

Table I. Energy of Adsorption (Change in Work of Adhesion with Change in Adsorption Density)

Solution Concentration		Quartz			
Mg Per Liter	Micromol Per Liter	Adsorption Density, Pct of Monolayer	Surface Tension, Erg Per Cm^{-2}	Contact Angle, °	X Calorie Per Mol
0.8	3.2	2	72.2	4	
4.3	17.5	5	71.3	12	2690
17.2	70	10	70.2	20	1460
80	318	25	64.9	28	504
135	550	50	61.4	34	301
240	980	100	56.7	40	97
292	1190	125	55	42	−20
		Hematite			
4.6	18.8	2	71.3	15	3830
21	86	5	69.9	22	2920
66	268	10	66.2	29	1965
132	540	15	61.5	35	1410
252	1030	25	56.3	40	240
550	2250	50	48.9	44	−60
980	4000	100	42.5	45	−60

Consideration of the formation of an electrical double layer appears sound, since electrokinetic measurements have shown that particles dispersed in distilled water carry an electric charge.[15] The system as a whole must be electrically neutral; consequently each particle must be surrounded by an electric double layer. The negative surface charge on quartz is attributable to specifically adsorbed hydroxyl ions. This charge is balanced by an equivalent charge of the opposite sign which is carried by ions (generally called *gegen* ions) in a diffuse layer extending from the adsorbed layer into the interior of the liquid phase. It may be thought that ferric oxide would be qualitatively similar to silicon oxide.

The simplest model of the electrical double layer is that of Gouy and Chapman.[16] The surface is con-

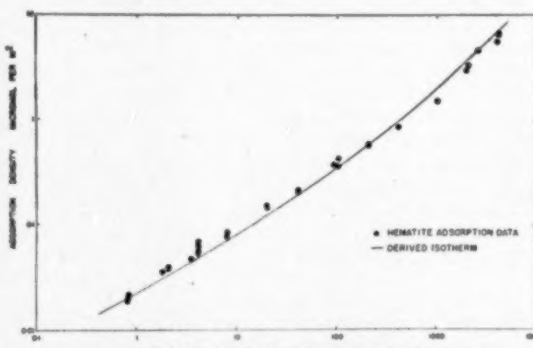


Fig. 11—Adsorption of dodecylammonium acetate on hematite fitted to an equation of the form $\Gamma = Ac^{0.5} + Bc$ with $A = 2.02\times10^{-9}$ and $B = 1.45\times10^{-7}$.

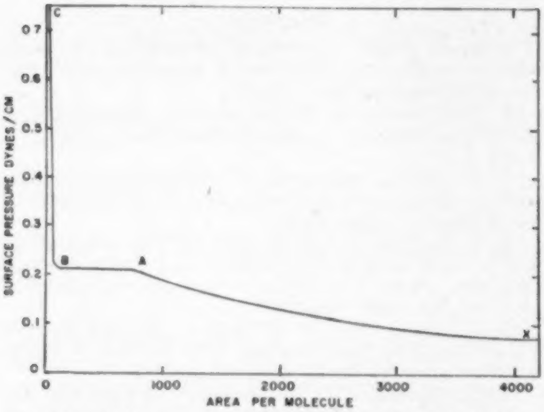


Fig. 12—Surface pressure vs area per molecule for myristic acid adsorbed on water at 14.5°C according to N. K. Adam, *The Physics and Chemistry of Surfaces.*[37]

sidered as a smooth plane with an homogeneous surface charge. The diffuse layer contains both positive and negative ions as the electrostatic attraction of the negative surface charge on the cations is counteracted by the thermal motion of these ions, which tends to equalize the distribution of ions throughout the liquid. The surface charge per unit area (σ_s) is numerically equal to the charge per unit cross section of the diffuse layer (σ_d).

The relation between the diffuse layer charge (σ_d), the potential drop across the diffuse layer (ψ_o), and the total electrolyte concentration (n ions per cc) is given by the Gouy-Chapman equation:

$$\sigma_d = -\sqrt{\frac{2\epsilon kT}{\pi}}\ \sqrt{n}\ \sinh\left(\frac{Ze\psi_o}{2kT}\right). \qquad [4]$$

In this equation ϵ is the dielectric constant of the liquid medium, k is the Boltzmann constant, T is the absolute temperature, e is the electronic charge, z is the valency of the gegen-ions, and *sinh* denotes the hyperbolic sine.

In the case of hematite, if it is accepted that the hydroxyl ion is the potential-determining ion, then at constant pH, ψ_o is constant, and Eq. 5

$$\sigma_d = A\sqrt{n} \qquad [5]$$

may be accepted as an approximation. Since the amine salt is almost completely ionized in the vicinity of pH6, and at great dilution, and since the amine salt is the only electrolyte added, Eq. 5 can be replaced by Eq. 6, which relates the charge per unit cross-section of the diffuse layer σ_d to the concentration of amine salt added, A being a constant:

$$\Gamma_{RNH_3^+} = \sigma_d = A\sqrt{c} \qquad [6]$$

If in addition to the gegen-ions the surface of the hematite has adsorbed either free amine or a reaction product, in other words, if it is postulated without specification of a definite reaction mechanism that

$$\Gamma_{TOTAL} = \Gamma_{RNH_3^+} + \Gamma_m \qquad [7]$$

an equation of the form of Eq. 3 may be obtained provided Γ_m is proportional to c. The latter condition is fulfilled in Langmuirian adsorption at high dilution.

This rationalization of the data which makes them fit Eq. 3 implies then that at all concentrations the adsorption is in two forms, one ionic at a relatively large distance from the surface as the diffuse part of a double layer, and the other of unspecified form located very near the surface.

A different rationalization of the data may also be defended. It is well known that the adsorption-surface tension data for many surface-active molecules on water, e.g., myristic acid, $C_{13}H_{27}COOH$, may be represented in the form of a diagram like Fig. 12, in which the reciprocal of the adsorption is plotted as abscissae and the surface pressure as ordinates. As the adsorption increases, the surface pressure increases; this is represented by the portion XA of the curve. At the area per molecule represented by A a new condition sets in represented by the section BA of the curve in which the surface pressure does not change while the adsorption increases from that corresponding to A to that corresponding to B. At B a second change occurs. For the portion of BC of the curve very great increases in surface pressure result from minute changes in adsorption. BC is accepted to represent a condensed film, AX a gaseous film, and AB a two-phase film consisting of islands of condensed film in an ocean of gaseous film. All these films are monomolecular in thickness with the molecules lying substantially flat in AX and increasingly erect in BC as the area per molecule is decreased.

If a similar situation existed in regard to the films of dodecylammonium ion on hematite it might well be expected that transformation at the equivalent of point B in Fig. 12 would be reflected in a break in the log Γ-log c curve, as drawn in Fig. 1. At this time it seems useful to call attention to this possibility, especially in the light of the ideas of two-dimensional mobility of adsorbate suggested by Hassialis and Myers.[19] Unfortunately the authors' measurements are still inadequate to justify pursuit of this intriguing suggestion.

On Contact Angle Measurements: Experimental data indicate that no simple relationship exists between adsorption density and contact angle θ. The apparent maximum value of θ, see Fig. 6, occurs at about the same adsorption density as the bends in the corresponding isotherms. Taggart et al[20] have attributed similar contact angle behavior to the adsorption of a second layer of collector by a mechanism involving the like-to-like attraction of hydrocarbon groups in the presence of a solvent.

The chief deterrent to a more exact correlation between contact angle and adsorption density stems from lack of information concerning the detailed distribution of the adsorbed agent in the solid-liquid interface. It seems reasonable to assume that collector ions held in the diffuse layer contribute relatively little to contact angle formation. On the other hand, the amount of reagent attached directly to the

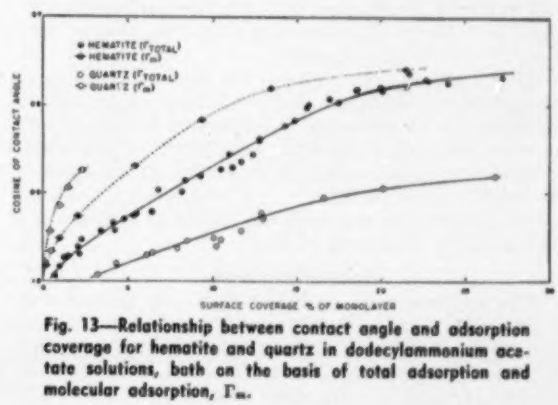


Fig. 13—Relationship between contact angle and adsorption coverage for hematite and quartz in dodecylammonium acetate solutions, both on the basis of total adsorption and molecular adsorption, Γ_m.

surface, aside from that in the double layer, has not yet been measured directly. Using adsorption Eq. 3, however, it is possible to estimate the value of Γ_m corresponding to any given value of Γ_{total}. Fig. 13 is a plot of cos θ vs Γ_{total} and cos θ vs Γ_m where Γ_{total} and Γ_m are expressed in percent of a monolayer. Contact angle data for the construction of this figure were obtained from Fig. 6.

Whereas it is quite clear that a definite adsorption density is required to obtain a finite contact angle in terms of Γ_{total}, the cos θ— Γ_m curves seem to pass through the origin in Fig. 13. This is what would be expected if in the absence of collector the adhesion between the liquid and solid were exactly equal to the cohesion of the liquid.

The existence of measurable contact angles and the attainment of excellent flotation with both hematite and quartz at total adsorbate surface coverages of only 4 to 5 pct of a monolayer (Γ_{total}) is of particular interest. Using Eq. 3 or Fig. 13 it appears that Γ_m for substantially complete flotation is well under 1 pct. Such a result is consonant with two ideas, 1—that the adsorbed entity is capable of lateral movement and 2—that it lies flat on the interface. Perhaps when contact is established the movable adsorbate moves so as to concentrate at the three-phase interface, and this may be why so incomplete a coating is nevertheless effective flotationwise. Such a situation would harmonize in part with W. O. Ostwald's[22] speculation of collector *adlineation* at a three-phase interline.

Summary

Using radio-assay technique and carbon-marked dodecylammonium acetate, an isotherm for the adsorption of amine from aqueous solution onto the surface of hematite has been established for a pH of 6 to 7 and a temperature of 21° to 24°C. At low concentrations log adsorption density is proportional to 0.6 log concentration. A bend occurs in the isotherm at a concentration of about 250 mg of amine salt per liter, corresponding to a surface coverage of 20 to 25 pct of a monolayer.

Reversibility of adsorption was established. As expected, adsorption density is independent of the specific surface of the mineral. The effect of pH on adsorption is small in acid solution, a ten thousandfold increase in hydrogen ion concentration decreasing adsorption about twofold.

Contact angles were measured on hematite and quartz surfaces immersed in aqueous amine acetate solutions using the captive bubble method. Temperature and pH were maintained essentially constant. The results are presented graphically and show the relation between contact angle θ and concentration and between cosine θ and surface coverage. No simple equation was found to connect adsorption with contact angle.

The work of adhesion for the mineral-air-liquid systems was calculated. Very flat maxima are found in the work of adhesion vs surface coverage curves at 0.35 and 1.05 parts of a monolayer for hematite and quartz respectively. The energy of adsorption is considerable for films very incompletely monomolecular, decreasing with increasing surface coverage actually changing in sign.

Acknowledgments

The authors wish to thank P. L. de Bruyn and D. W. Fuerstenau for their helpful suggestions and criticisms. They also express appreciation to the U. S. Atomic Energy Commission and to Armour & Co. for making this research possible.

References

[1] P. L. de Bruyn: Adsorption of Dodecylammonium Acetate on Quartz. Ph.D. thesis, Massachusetts Institute of Technology (May 1952).

[2] F. W. Bloecher, Jr.: A New Surface Measuring Tool for Mineral Engineers. MINING ENGINEERING, (1951) **3**, p. 255.

[3] C. S. Chang: Adsorption of Barium and Laurate Ions on Quartz. Ph.D. thesis, Massachusetts Institute of Technology (June 1951).

[4] H. J. Harwood and A. W. Ralston: The Synthesis of Lauric Acid and Dodecylamine Containing Carbon Fourteen. *Journal of Organic Chemistry* (September 1947) **12**, No. 5, pp. 740-741.

[5] S. C. Brown and W. W. Miller: Carbon Dioxide Filled Geiger-Muller Counters. *The Review of Scientific Instruments* (1946) **18**, No. 7, p. 496.

[6] A. M. Gaudin, P. L. de Bruyn, F. W. Bloecher, Jr., and C. S. Chang: Radioactive Tracers in Flotation. *Mining and Metallurgy* (August 1948) **29**, p. 432.

[7] F. W. Bloecher, Jr.: Concerning the Adsorption of Dodecylamine on Quartz. M.A. thesis, Massachusetts Institute of Technology (June 1949).

[8] A. F. Taggart, T. C. Taylor, and C. R. Ince: Experiments with Flotation Reagents. *Trans.* AIME (1930) **87**, p. 285-368.

[9] Guido R. M. delGuidice: The Bubble Machine for Flotation Testing. *Engineering and Mining Journal* (1936) **137**, p. 291.

[10] R. Schuhmann, Jr., and B. Prakash: Effect of $BaCl_2$ and Other Activators on Soap Flotation of Quartz. *Trans.* AIME (1950) **187**, p. 591.

[11] Robert B. Dean: The Gibbs—A Rational Unit for Adsorption. *Journal of Physics and Colloid Chemistry* (1951) **55**, pp. 611-612.

[12] Linus Pauling and Sterling B. Hendricks: The Crystal Structure of Hematite and Corundum. *Journal of the American Chemical Society* (1925) **49**, pp. 781-790.

[13] Ralph W. G. Wyckoff: *Crystal Chemistry*. Vol. I, Chap. V, text p. 11, illus. p. 3. Interscience Publishers Inc., New York, 1951.

[14] Herbert H. Kellogg, and Hugo Vasquez-Rosas: Amine Flotation of Sphalerite-Galena Ores. AIME (1946) *TP 1906*.

[15] Everett J. Hoffman, G. E. Boyd, and A. W. Ralston: Studies on High Molecular Weight Aliphatic Amines and Their Salts. VIII. Soluble and Insoluble Films of the Amine Acetates. A. The Surface Tension of Aqueous Solutions of Dodecylammonium Acetate, *Journal of the American Chemical Society* (1940) **62**, p. 2375.

[16] A. W. Ralston, C. W. Hoer, and C. Hoffman: Studies on High Molecular Weight Aliphatic Amines and Their Salts. IV. Electrical Conductivities of Aqueous Solutions of the Hydrochlorides and Acetates of Dodecyl— and Octadecylamines. *Journal of the American Chemical Society* (1940) **62**, pp. 97-103.

[17] N. K. Adam: *The Physics and Chemistry of Surfaces*, p. 50. Oxford University Press, London, 1941.

[18] E. J. W. Verwey, and J. Th. G. Overbeek: *Theory of the Stability of Lyophobic Colloids*. Elsevier Publishing Co. Inc., 1948.

[19] M. D. Hassialas, and C. G. Meyers: Collector Mobility and Bubble Contact, *Trans.* AIME (1951) **188**, pp. 961-968.

[20] A. F. Taggart, N. Arbiter, and H. H. Kellogg: The Mechanism of Collection of Metals and Metallic Sulphides by Amine Salts. *Trans.* AIME (1943) **153**, p. 517.

[21] A. M. Gaudin, and F. W. Bloecher, Jr.: Concerning the Adsorption of Dodecylamine on Quartz. *Trans.* AIME (1950) **187**, pp. 449-505.

[22] W. O. Ostwald: Theory of Flotation. *Kolloid Z.* (1932) **58**, pp. 179-183; **60**, pp. 324-340.

[23] John G. Morrow: Adsorption of Dodecylammonium Acetate on Hematite and Sphalerite. Ph.D. thesis, Massachusetts Institute of Technology, 1952.

Magnetic Attraction of Stacked Drill Rods

by John L. Baum

Tests show that 50 times the earth's normal field can exist near stacked drill rods. Protection against the effect of these strong fields can be obtained by means of a removable sleeve of common iron pipe.

GEOLOGISTS and engineers working around a diamond drill rig have often had the opportunity to observe the magnetic attraction of drill rods pulled out of the hole for core removal. This is sometimes an amusing pastime, but this same magnetic force inadvertently applied to a compass needle can cause it to lose its polarity entirely or to become reverse polarized when placed in the immediate vicinity of stacked rods. The first recommendation, of course, would be to avoid the rods, but in surveying an operating drillhole this is not always possible; therefore steps must be taken to neutralize the magnetic effect of the drill rods.

Early in the summer of 1949 the geological department of the New Jersey Zinc Co. undertook at Franklin, N. J., an extensive program of surveying the course of deep diamond drillholes. The majority of the holes were surveyed while in the process of being drilled, and considerable difficulty was encountered. A pattern for the deviation of drillholes had been established for the district from surveys in holes from which the drill rig had been removed. It was observed that a certain operating deep drillhole being surveyed did not fit this pattern. In the resulting confusion of repeated surveys and cementing a plug for wedging operations, the lower 1800 ft of the hole was lost. Because of this incident studies were initiated to determine the source of the difficulties and to develop safeguards against recurrence of faulty surveys.

J. L. BAUM is Chief Geologist, Franklin-Sterling Operations, the New Jersey Zinc Co., Franklin, N. J.

Discussion on this paper, TP 3953I, may be sent (2 copies) to AIME before Feb. 28, 1955. Manuscript, Oct. 13, 1953.

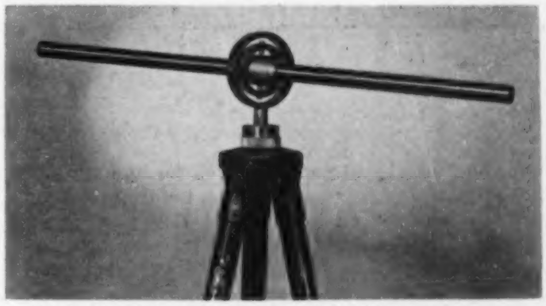
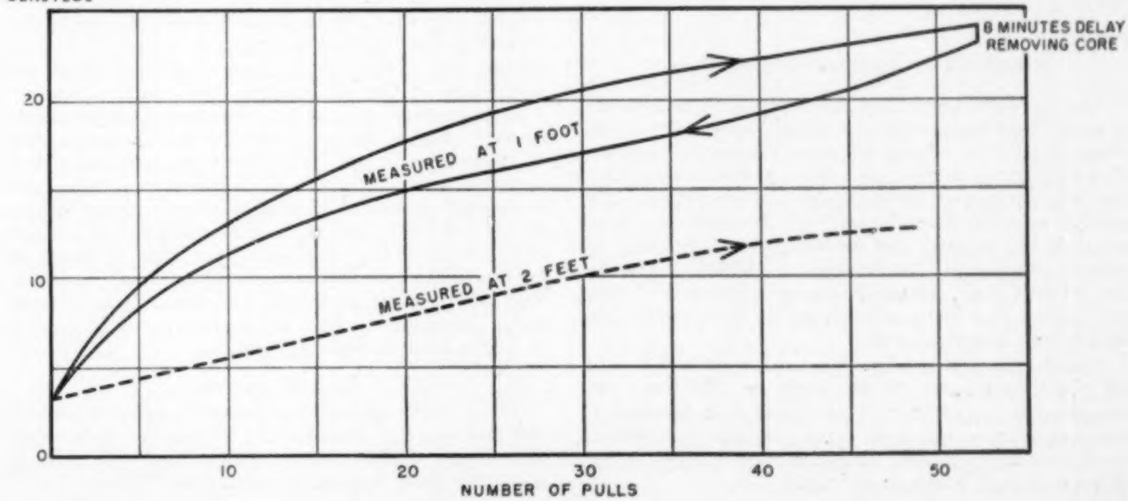


Fig. 1—Oscillating magnet mounted for field measurements.

Using a hand magnet easily shows that the polarity of a compass needle can be reversed if rotation of the needle is hindered through tilting of the compass or clamping of the mechanism. Such experiments are not recommended, especially in the case of the clockwork type of instruments. A magnetized hairspring in a clockwork instrument will cause the compass card to assume a periodic motion which will not stop until the clockwork runs down.

Routine check readings of instrument north before and after each survey are not always sufficient to catch instances of reversed polarity of the compass needle. Although the majority of instances probably take place while the instrument is being removed from the hole with needle in fixed position, it is demonstrable that a sluggish needle, weakened during a previous test, can be reverse polarized

Fig. 2—A drill rods, 30-ft pulls.



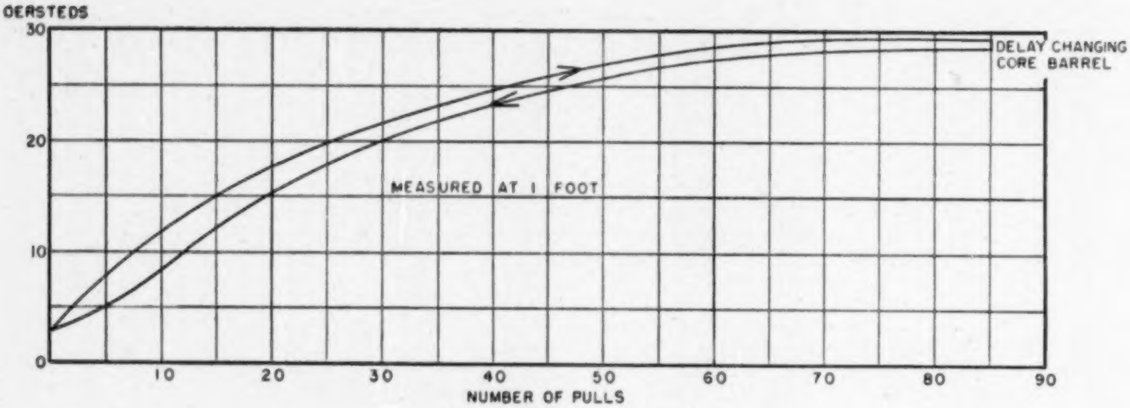


Fig. 3—8 drill rods, 60-ft pulls.

while being placed into position for lowering. In the case of polarity reversed both before and after a test, the introduced error defies detection by any means other than repeated surveys.

Assistance of the New Jersey Zinc Co. research department at Palmerton, Pa., was requested, and R. K. Waring of the research staff kindly offered a number of suggestions. He stated that manufacturers of drillhole survey equipment can make a contribution to partial solution of the problem by incorporating a magnetic needle of greater permanence and higher strength than was furnished in the devices tested. Waring also pointed out that experiments show that surrounding a compass with soft iron, such as a piece of pipe, will shield it from the effect of a magnetic field.

At the drill rig a length of pipe split longitudinally and hinged for easy removal is now used. This magnetic shield hangs on the instrument container by virtue of a constriction welded on top of the pipe. When the container enters the drillhole casing projections hold back the shield. It can then be removed if desired, to be replaced when the instrument container is withdrawn. Loading of the container is accomplished 5 ft or more from the stacked rods. Because the effect of a magnetic casing has not caused trouble in surveys where the field of the stacked rods has been neutralized, little effect is ascribed to the casing in influencing the accuracy of survey readings.

Instrument to Measure Field Strength

The research department was requested to develop a method of measuring the actual field strength of magnetic forces which act upon survey compasses. The oscillating magnet was selected for this purpose because of simple construction and operation. The period of oscillation depends on the magnetic moment of the magnet and the strength of the field in which it oscillates. The first magnet tested at Franklin worked well, checked against later results, but the device was hung only on a thin nichrome wire, which failed frequently.

The second instrument, Fig. 1, consists of a rod of 36 pct cobalt steel, 3/8 in. diam and 30 cm long, mounted in a cylinder. The cylinder is pivoted at top and bottom within an inner gimbals ring, which in turn is supported in an outer rigid gimbals ring. Miniature ball bearings are used.

The cobalt-steel bar was heat-treated by standard procedures and then magnetized. The device was calibrated in a magnetic field of known strength.

Field Strength Measured

A series of measurements were taken at several operating drillholes with this calibrated instrument to determine the field strength encountered near the rods. Precautions were taken to obtain accurate data and to avoid any outside influences.

From the data accumulated in field measurements it is apparent that a number of variables affect the recorded magnetic field of stacked drill rods. In order of decreasing importance these are: distance of the instrument from the rods, number of rod pulls, and length of time the rods have been out of the hole. Of minor importance are the size of the rods, the length of each pull, and the manner in which the stacked rods are grouped. Graphs prepared from some of the data illustrate a few of the possible modifications of values that can be ascribed to one or more of the above listed variables, see Figs. 2 and 3.

Measurements show that stacked rods at a distance of 1 ft can exert a force of almost 30 oersteds, or 50 times the earth's normal field. At 2 ft, other conditions being equal, the force is nearly 18 oersteds. Values at 3 ft can be 6½ oersteds, and at greater distances the force is relatively slight. Stacked rods lost part of their magnetism quickly, and during the period of core removal were observed to lose up to 1¾ oersteds. As might be expected, the bottom of a stack of drill rods is the north pole of the bar magnet produced.

Examination of the accompanying illustrations suggests that a magnetic field of a value in excess of 30 oersteds is not likely to be encountered a foot or more from any stack of diamond drill rods used in current practice. This is because increase in size of the magnetic source is ultimately offset by loss of polarity during the length of time it takes to hoist a large number of rods. It follows, therefore, that 30 oersteds probably represent a maximum value for magnetic field strengths at a distance of 1 ft under present hoisting speeds.

Acknowledgment

The author wishes to express his appreciation to the New Jersey Zinc Co. for permission to publish this article and to the company's research department for their technical assistance.

Near-Surface Hydrocarbons and Petroleum Accumulation at Depth

by Leo Horvitz

Microanalysis of near-surface soils for hydrocarbons is the basis of a method for locating gas and oil deposits. To substantiate this technique, evidence of vertical migration of hydrocarbons from petroleum accumulations is presented. Tabulated data relevant to hydrocarbon surveys conducted in several petroleum provinces are included.

PETROLEUM and natural gas are composed principally of the saturated hydrocarbons ranging from methane, the lightest, to nonvolatile liquids and solids containing approximately thirty-five carbon atoms. A technique for locating buried accumulations of these hydrocarbons before drilling obviously requires that some of the hydrocarbons leave the deposit and migrate toward the surface of the earth where they may be detected in their original form.

Earliest attempts to link near surface hydrocarbons to petroleum at depth were apparently made by Laubmeyer[1] in Germany and by Sokolov[2] in Russia. These investigators collected samples of soil air from boreholes one to two meters deep and analyzed them for traces of hydrocarbons. They found that soil air over producing areas is richer in these constituents than is soil air over barren areas.

Since 1936 work on petroleum exploration techniques of this type has been going on in this country. However, instead of determining hydrocarbon content of soil air collected in the field, investigators analyze samples of the soil itself[3-5] for adsorbed and occluded hydrocarbons, which are released by suitable treatment and found in larger amounts than are the quantities reported for soil air. Difficulties often encountered in collecting gas samples in the field, moreover, are eliminated when soil is used as the sampling medium.

Field Procedure: Sample locations are first surveyed over the area to be investigated. Care is taken to locate the stations at considerable distances from roads, pipelines, drilling wells, and other sources of contamination. The borehole may be dug with a bucket-type hand auger or with mechanical drilling equipment. Lubricants are avoided in either case. When the desired depth is reached, a sample is brought to the surface, placed in a pint glass jar or can, and securely sealed. Sample containers are carefully labeled and delivered to the analytical laboratory. Generally a satisfactory sampling depth range is 8 to 12 ft. In some regions, however, satisfactory data are obtained from samples collected at much shallower depths. Such is the case, for example, in areas of west Texas where the limestone and caliche near the surface occlude hydrocarbons and prevent their rapid escape to the atmosphere.

In carrying out broad reconnaissance surveys in search of large features, considerable time is saved by first taking samples one-fourth to one-half mile apart along profiles about one mile apart. If the analytical data indicate a hydrocarbon anomaly of interest, additional samples are taken to produce a more dense and uniform sampling pattern within the interesting area. This sampling program is particularly adaptable to areas that are sectionized. In areas covered with a network of roads, sampling along these roads facilitates the reconnaissance survey. Actual sampling density used depends upon areal extent of features expected. When flanks of piercement-type domes where accumulations may be only several hundred feet wide are sampled, stations are often no more than 200 ft apart.

Analytical Technique: Of the hydrocarbons composing petroleum, only the more volatile would be expected to reach the surface of the earth. The analytical technique, therefore, was developed to determine only those constituents that exert a vapor pressure at room temperature. Actually, in near-surface soils, only a very small part of the hydrocarbons are heavier than pentane. Details of the analytical technique have previously been reported.[6,7] Only a brief description of the methods will be presented here.

A weighed portion of the sample, about 100 g, is first treated with an aqueous solution of copper sulphate and then with phosphoric acid in a partial vacuum. The copper sulphate prevents the reaction of the acid with carbides that may be present because the sample has been contaminated by auger particles. Such a reaction may produce spurious methane. The role of the acid is to decompose any carbonates present, thereby helping to release the hydrocarbons. The carbon dioxide is removed with potassium hydroxide and the flask containing the

L. HORVITZ, Member AIME, is Consulting Chemist and Geochemist, Horvitz Research Laboratories, Houston, Tex.

Discussion on this paper, TP 3927L, may be sent (2 copies) to AIME before Jan. 31, 1955. Manuscript, Feb. 9, 1954. New York Meeting, February 1954.

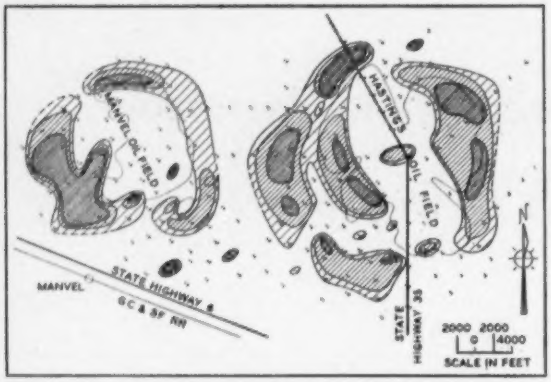


Fig. 1—Hydrocarbon survey of the Manvel and Hastings oil fields, Brazoria County, Texas.

sample is then heated 30 min. at 100°C. This mild heat treatment does not permit decomposition of organic matter that may be present. The carbon dioxide free sample is collected in a previously evacuated tube and analyzed.

To analyze the extracted gases, low temperature fractionation and combustion methods are employed. The gaseous mixture is passed through potassium hydroxide solution, concentrated sulphuric acid, ascarite, and phosphoric anhydride before entering the analytical apparatus proper. The concentrated sulphuric acid removes the oxygen-containing compounds referred to as *pseudo-hexane* in a previous paper.[4] The routine analysis has been standardized to include two separate fractions, 1—methane and 2—ethane and heavier hydrocarbons. The methane is determined separately because this hydrocarbon may be present in the soil as a result of decaying organic matter. In conjunction with appropriate traps and valves, the separation is conducted at the temperature of liquid nitrogen, −196°C. Methane is gaseous at this temperature, whereas ethane and heavier hydrocarbons are condensed. The methane is determined by combustion of the noncondensable mixture over a glowing platinum wire. The resulting carbon dioxide is collected and measured and from its quantity the methane is readily computed. The quantity of ethane and heavier hydrocarbons is determined by first vaporizing and measuring the volume of the condensed fraction and then measuring the carbon dioxide resulting from combustion of this fraction with purified air. The increase in the final volume is a measure of the quantity of ethane and heavier hydrocarbons initially present. Sensitive McLeod gages are employed to measure the pressures from which the volumes of hydrocarbons are calculated.

The total volume of the gas sample initially prepared is known and the various parts of the analytical apparatus are calibrated, permitting calculation of volumes of gas used for the different determinations. Volumes of the various constituents are thus readily determined. Weights of the different fractions are calculated from the gas laws and the final results expressed in parts per billion by weight (dry basis) of the soil sample. Data are expressed in these units for convenience. They may be expressed in other terms, for example, in cubic centimeters per kilogram. For the case of ethane and heavier hydrocarbons (expressed as butane) one part per billion by weight is equivalent to approximately 0.0004 cc per kilogram of soil.

Analyses of duplicate portions of numerous soil samples yield values for the duplicates that agree within limits of 20 pct for the range of 10 parts per billion and above. For the case of very low values, the percentage differences are of course much wider.

Hydrocarbon Distribution Patterns: Data obtained by the soil analysis technique indicate the usual hydrocarbon distribution pattern over a large producing area to be one in which low concentrations are found over the center of the productive area, whereas relatively high concentrations occur at the edges. Outside the bands of high concentration, low values are again obtained. Occasionally an anomaly surrounded by a background of low values is found in which high values are associated with the entire productive area. This type is usually associated with accumulations of relatively small areal extent. Another pattern sometimes encountered is one in which values found over the productive area are considerably higher than those obtained in the background areas, with still higher concentrations at the edges of the producing area.

Only a weak anomaly, and often none, is found over a depleted field. Apparently when the source at depth begins to disappear, hydrocarbons near the surface also begin to disappear.

Fig. 1 shows the results of an experimental survey conducted in 1946 over the Manvel and Hastings oil fields, Brazoria County, Texas. Samples were collected at depths ranging from 8 to 12 ft. Ethane and heavier hydrocarbon values, expressed in parts per billion by weight, have been plotted at the station location symbols. The following groups of values are enclosed by the various contour lines: 25 to 49; 50 to 99; 100 and above. To display the variations in hydrocarbon concentration over the area sampled several degrees of shading have been used. Values below 25 parts per billion by weight are in the unshaded areas, values from 25 to 49 parts per billion in the areas of lightest shading, values from 50 to 99 in the zones of intermediate shading, and values of 100 parts per billion and above in the most heavily shaded areas. The broken lines, within the anomalous areas, represent the outer limits of the producing areas of the two fields.

The hydrocarbon anomalies are distinct and of the more general type. The anomaly associated with the Hastings field is considerably stronger than that over the Manvel field. The Hastings field, discovered in 1934, is one of the largest in Texas and only a relatively small part of its reserve has been produced. The Manvel field, discovered in 1931, has a much smaller reserve and has produced for a longer time. The low values over the main producing areas suggest that no contamination of the soil was caused by the producing wells.

The anomaly associated with the Hastings field contains a double band of high hydrocarbon concentration on the west side. The inner band is apparently associated with the west side of the present producing area, while the outer band, which extends beyond the producing area, may be associated with a new, potentially productive section. On the west side of the Manvel field a possible extension is also indicated. The main producing zones of the Manvel and Hastings fields are in the Frio formation. The anomalous conditions on the west flanks of these fields may reflect accumulations at greater depth, perhaps in the Vicksburg or Yegua formations.

This survey indicates the importance of the acid treatment in the extraction procedure. In an earlier

survey[4] of the Hastings field conducted in 1937, prior to the introduction of this improvement, values of a much lower magnitude were obtained, and although an anomaly developed a much less distinct pattern resulted. Apparently heating of samples without the acid treatment liberates only the loosely held hydrocarbons.

It is of interest to point out that the methane data yielded patterns over the Manvel and Hastings fields similar to those obtained from the ethane and heavier hydrocarbons. Methane is not considered significant in marshy areas but is sometimes the most significant constituent determined in near-surface soils. From a dry gas deposit, for example, only methane emanates in significant amounts and produces the near-surface anomaly.

Fig. 2 shows a portion of a very large survey conducted in Harris, Brazoria, and Galveston Counties, Texas, and completed in 1952. The portion of the survey which is presented includes 227 stations which were sampled at depths of 8 to 12 ft and covers approximately 25,000 acres. This survey illustrates the type of data obtained and the interpretation made prior to the discovery of petroleum accumulation. Values shown on the map are for the ethane and heavier hydrocarbons, expressed in parts per billion by weight. The same contour levels and shading system were used as for the area in Fig. 1.

Four hydrocarbon anomalies, A-1, A-2, A-3, A-4, and three leads, L-1, L-2, L-3, are indicated on the map. This survey is particularly interesting because it contains anomalies of the different types that have been encountered. Anomaly A-1 is of the type containing an area of low concentrations bordered by high values; A-2 is suggestive of the type made up of an area of hydrocarbon concentration greater than the background, with still higher concentrations at the edges of the anomaly; A-3 is made up of an area of high concentrations; and anomaly A-4 appears to be a combination of two types, the northern half being similar to A-1 and the southern part similar to A-3. To define the leads, more data are obviously needed. For example, for the case of lead L-2, data are required within the lake area, outlined on the map, and in the areas immediately to the north and west of the lead. Collection of samples within the lake area was not attempted and permission to sample outside the area of the lead could not be obtained at the time the survey was conducted.

The nonproductive wells drilled prior to the completion of the survey were found to be located in the background. Of the five wells drilled after completion of the survey, only one was located within a hydrocarbon anomaly. This was the No. 1 Hecker well, which was completed as a gas distillate discovery. The commercial value of this new accumulation will not be known, of course, until additional development occurs.

From the data of Fig. 2 the average background value is calculated to be only eight parts per billion while the average anomalous value is 145 for A-1, 74 for A-2, 101 for A-3, and 81 for A-4. Ratios of the anomalous values to the background, therefore, range from 9 to 18. Another interesting observation is that the first contour level, containing values from 25 to 49 parts per billion by weight, may be omitted without producing significant variations in the anomalies.

The average background value is not constant for all areas and can be determined to a reasonably accurate degree only if a large area is sampled. The determination of significant anomalous values for a particular area may be facilitated by extending the survey, where possible, to include part of a productive area. Generally the background values for areas in the Gulf Coast are low, usually below 25 parts per billion. In many sections of north Texas and west Texas, and other petroleum-bearing regions, however, average background values may approach 100 parts per billion for ethane and heavier hydrocarbons. In such areas of high background concentration, the anomalous areas are still readily recognized if sufficient data are available. The average of the values that are usually associated with a significant anomaly is of the order of 300 pct, or more, greater than the average background value.

Vertical Migration of Hydrocarbons from a Petroleum Accumulation: A direct relationship between the data presented in Figs. 1 and 2 and petroleum accumulation at depth would be admitted readily if hydrocarbon leakage from the accumulation to the surface of the earth could be demonstrated. An obvious method of determining whether or not such migration occurs involves the collection and analysis of formation cores from the surface to the petroleum accumulation and the comparison of the hydrocarbon data obtained from these cores with similar data for cores taken from wells drilled in barren areas. Unfortunately, continuous cores of the type required are never available; usually cores are available for only very short sections of wells. Formation cuttings are, however, always produced during the drilling of wells. A disadvantage of this sample medium is that the cuttings are washed with hot mud as they are pumped to the surface, which causes an appreciable reduction of their hydrocar-

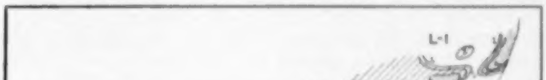


Fig. 2—Survey of an area in Harris and Galveston Counties, Texas, which illustrates the various types of hydrocarbon distribution patterns encountered. Encircled wells were drilled after completion of survey.

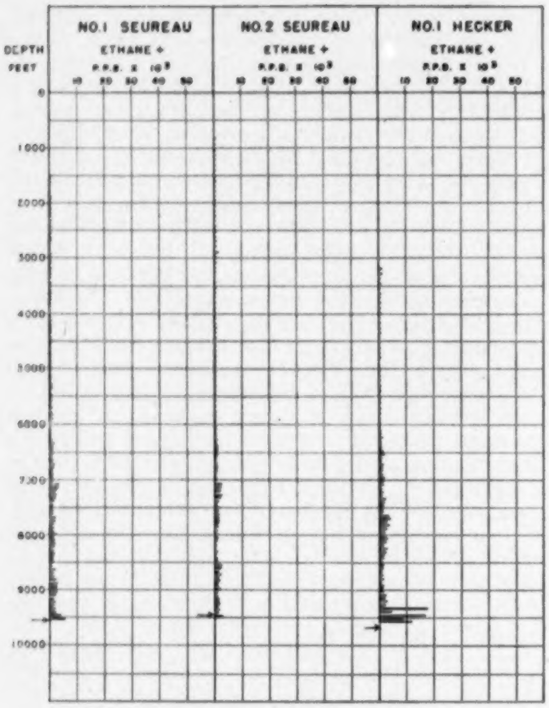


Fig. 3—Hydrocarbon logs of three wells drilled in the Seabrook area, Harris County, Texas. The Hecker well encountered a gas condensate zone at 9690 ft, indicated by arrow. Barren equivalent zones in other two wells are also indicated by arrows. Only apparent source for high hydrocarbon values in lower part of Hecker log is petroleum accumulation below.

bon contents. In addition, data for the upper 2000 to 3000 ft of section drilled are not usually available because this section, especially along the Gulf Coast, is composed of soft clays and sands and returns from the well are thoroughly mixed with the drilling mud and impossible to separate. In deeper portions of the well firm shale and consolidated sands are encountered which can be readily separated from drilling fluid. In spite of these objectionable characteristics, a great many samples from many different wells and formations have been collected and significant data have been obtained from them.

Normally samples are collected from the shale shaker at the end of each 30 ft of section drilled. The samples are placed in pint glass jars or sealed in cans and brought to the laboratory where they are washed free of drilling fluid. Composite samples are usually prepared for each 60 to 90 ft of drilling. When more detailed information is required a greater sampling density is used.

The gas extraction and hydrocarbon analysis procedures used in connection with the cuttings are the same as those described for the determination of hydrocarbons in near surface soils. Just as in that case, undried samples are used and the moisture content, needed in the calculations, is determined from a portion of the sample separate from that used in the analysis. Usually the methane, the ethane and heavier hydrocarbon data, and the total hydrocarbon data are plotted in the form of a log. A scale of 1 in. to 1000 ft is used so overall patterns that develop can be viewed. Additional information can be obtained by separating the ethane and heavier hydrocarbons into ethane-propane-butane and pentane and heavier hydrocarbon fractions.

In Fig. 3 are shown the plotted ethane and heavier hydrocarbon data obtained from cuttings collected from three wells drilled in the Seabrook area of Harris County, Texas. The No. 1 Seureau is located about 2800 ft north of the No. 2 Seureau, and the No. 1 Hecker well, which appears on Fig. 2, is located approximately two miles from the No. 2 Seureau in a southwesterly direction. The two Seureau logs are generally similar. The log of the Hecker well is different in that much greater hydrocarbon values were obtained for the bottom several hundred feet of this well. The only apparent explanation for this difference is the fact that a gas distillate accumulation, noted on Fig. 3 by an arrow, was encountered at 9690 ft in the Hecker well, whereas the corresponding zones in the other two wells were nonproductive. The zones in the Seureau wells that correspond to the Hecker zone are also indicated by arrows and were determined by correlation of the electrical logs of the three wells. Cuttings for the section immediately above the Hecker accumulation were not taken. When the three logs down to the Hecker zone equivalent are considered, it is apparent that a petroleum reservoir produces a measurable effect for a considerable distance above the deposit. If the hydrocarbons in the lower part of the Hecker well were indigenous, then the same order of magnitude of values should have been obtained in the corresponding sections of the other two wells.

Table I. Summary of Exploration Experience

Area	Coverage in Acres	Anomalies over Producing Fields Covered by Surveys		New Anomalies		Results	
		Present	Absent	Revealed by Surveys	Drilled	Productive	Dry
Texas Gulf Coast	1,018,000	19	0	45	20	13	7
North Texas	201,000	6	2	8	4	3	1
South Texas	64,000	4	0	5	4	2	2
West Texas	283,000	4	0	9	3	2	1
Louisiana	219,000	1	0	11	4	2	2
Mississippi	239,000	2	0	5	2	1	1
Georgia	750,000	0	0	10	0	0	0
Florida	50,000	0	0	1	1	0	1
California	30,000	1	0	5	0	0	0
South America:							
Ecuador	380,000	0	0	10	1	0	1
Canada:							
British Columbia	90,000			Large anomalous area with bands of high concentration parallel to strike. Scattered gas wells associated with areas of low concentration between these bands. Hydrocarbon survey has been confirmed by additional development.			
Totals	3,324,000	37	2	109	39	23	16

An interesting set of logs is shown in Fig. 4. Data were obtained from cuttings collected from three wells drilled in the North Thompson field of Fort Bend County, Texas. Unfortunately, only samples from the bottom 450 ft of the 1-B Scanlan well were available for analysis; nevertheless, a distinct buildup in hydrocarbon concentration is apparent above the oil reservoir, which was encountered at 7957 ft. This well was completed in the Vicksburg formation from perforations at 7957 to 7965 ft as an excellent producer. The 1-C and 1-E wells, located 2600 ft northeast and 2100 ft east of the 1-B, respec-

tively, and outside the producing area, encountered salt water with only small amounts of oil in this zone. The values, in the sections immediately above the producing horizon equivalent, are considerably lower than those in the corresponding section of well 1-B. These data again serve to suggest that hydrocarbons migrate vertically in significant quantities from a petroleum reservoir.

Many logs similar to those shown in Figs. 3 and 4 have been prepared and some of them appear elsewhere.[8, 9] While the nature of the sampling medium makes it impossible to follow the hydrocarbons to the surface, cases have been observed in which appreciable values have been obtained for several thousand feet above the accumulation. Wells located at the edges of petroleum deposits often produce longer sections of relatively high hydrocarbons than do wells that are centrally located.

Exploration Experience: Because of the difficulties encountered in definitely establishing either a theoretical or experimental basis for vertical leakage of hydrocarbons from a petroleum accumulation to the surface, the value of soil hydrocarbon data in exploration must be determined experimentally by the accumulation and study of a great deal of data. During the 11-year period ending in 1953 a total of 130 hydrocarbon surveys have been conducted. Of these, 61 covered 20,000 acres or more. In Table I only data relevant to the group of larger surveys are included because an area of at least 20,000 acres should be sampled to permit an adequate interpretation. The status of the areas at the time the surveys were completed is noted and new development that has taken place since is indicated.

The table shows that of 39 anomalies considered to be associated with oil or gas accumulation, 59 pct were confirmed. Of the 69 smaller surveys conducted, a number revealed significant anomalies, and of 11 anomalies drilled, 4, or 36 pct were found to be productive.

While discoveries of new oil or gas deposits made on the basis of hydrocarbon surveys alone are included in Table I, credit for all the discoveries is not claimed. For purposes of evaluation, however, the technique was credited with a confirmation if a petroleum accumulation was found within an anomaly provided that the survey was completed prior to drilling. Similarly, a failure was recorded when a nonproductive well was drilled within a hydrocarbon anomaly.

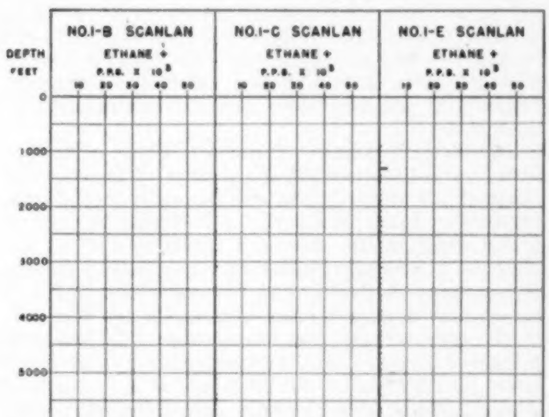


Fig. 4—Hydrocarbon logs of three wells located in the North Thompson field, Fort Bend County, Texas. The No. 1-B Scanlan is the only producer and shows much greater hydrocarbon values in the section above the productive horizon than do the others. Vertical migration of hydrocarbons from a petroleum accumulation is strongly suggested by the 1-B log. Lowest line, marked by asterisk, represents off-scale value of 72,640 parts per billion by weight.

Conclusions

The technique described in this paper differs from all other methods of exploration in that it involves measurement of some of the very constituents that make up natural gas and oil deposits, namely, the saturated hydrocarbons. Data presented offer evidence that the hydrocarbons observed near surface originate in buried deposits, suggesting a direct approach to locating petroleum.

Because no single method of exploration is believed to be universally applicable, this technique should be used in conjunction with others, particularly with subsurface geology and the seismic method. Hydrocarbon surveys are particularly important in the reconnaissance phase of exploration whereby anomalies which may serve as targets for the seismic method may be located. While hydrocarbon data may serve to outline a potential oil or gas accumulation, no evidence as to the depth to the accumulation and no structural information can be obtained from these data. Seismic data can throw light on these problems, but in the event a strong hydrocarbon anomaly is found not to be associated with structure, the possibility that it is reflecting a stratigraphic trap should not be overlooked.

Acknowledgment

The writer wishes to express his thanks to Beersheba Corp. for use of the data shown in Fig. 3 and to Christensen and Matthews for release of the hydrocarbon logs of the North Thompson field.

References

[1] G. Laubmeyer: A New Geophysical Prospecting Method, Especially for Deposits of Hydrocarbons. *Petroleum* (1933) **29**, pp. 1-4.

[2] V. A. Sokolov: Summary of the Experimental Work of the Gas Survey. *Neftyanoye Khozyaystvo* (1935) **27**, pp. 28-34.

[3] E. E. Rosaire: Shallow Stratigraphic Variations over Gulf Coast Structures. *Geophysics* (March 1938) **3**, pp. 108-109.

[4] Leo Horvitz: On Geochemical Prospecting. *Geophysics* (July 1939) **4**, pp. 210-225.

[5] Leo Horvitz: Recent Developments in Geochemical Prospecting for Petroleum. *Geophysics* (October 1945) **10**, pp. 487-493.

[6] Leo Horvitz: Chemistry in Exploration for Petroleum. Preprint in *Papers presented before the Petroleum Division*, American Chemical Society, St. Louis Meeting, April 7-11, 1941.

[7] J. J. Jakosky: *Exploration Geophysics*, 2nd ed., pp. 944-948. Trija Publishing Co., 1950.

[8] Leo Horvitz: Geochemical Well Logging. *A Symposium of Subsurface Logging Techniques*, pp. 89-94. University of Oklahoma, 1950.

[9] E. E. Rosaire: Geochemical Prospecting for Petroleum. Bulletin of the *American Association of Petroleum Geologists* (August 1940) **24**, pp. 1418-1426.

Variable resistivity in a surface layer may lead to misinterpretation. Errors can sometimes be avoided if the effect can be recognized and accounted for.

Effect of a Variable Surface Layer on Apparent Resistivity Data

by Harold M. Mooney

WHEN apparent resistivity data are taken with the symmetrical Wenner 4-electrode spread, a fixed center position is used and readings are taken for values of electrode separation. Basic data consist of apparent resistivity plotted against separation of adjacent electrodes. The interpreter attempts to infer geologic structure, such as the depth to discontinuities and the nature of subsurface earth materials.

An earlier paper[1] described methods for interpreting resistivity data. All of these involve a severe assumption, namely that the earth in the region of interest consists of horizontal layers, electrically homogeneous and isotropic. The actual earth never satisfies this assumption exactly and may deviate from it so much that none of the above methods can be applied. Attempts in three directions have been made to modify the assumption so that it approaches known geologic complexity more closely.

First, curves have been calculated for dipping discontinuities. Stern[2] and Aldredge[3] chose a few widely separated dip angles. Trudu[4] confined his attention to small dips. Berel'kovskiy and Zubanov[5] computed gradient curves for widely separated dip angles. Unz[6] has given the most complete solution, with a brief attempt to treat the three-layer case.

Second, anisotropy can be taken into account. It seems geologically probable that layered materials have different vertical and horizontal conductivities. Cagniard,[7] Maillet,[8] and Pirson[9] set up methods for finding an equivalent hypothetical isotropic medium. Standard interpretation methods can be applied to this, and the actual medium can then be deduced. Belluigi[10] discounts the practical importance of anisotropy; Geneslay and Rouget[11] do not agree with his conclusion.

Third, the effect of variable resistivity in a layer can be considered. Keck and Colby[12] examine the mathematics of an exponential increase in a surface layer. Several authors, for example, Stevenson,[13] consider a continuous variation of resistivity with depth. The present paper deals with a linear variation of resistivity in a surface layer.

Geologically, surface variations should be expected. Unconsolidated materials such as glacial drift show marked irregularities over short distances. The effects of weathering change with depth. The moisture content of material above the water table may vary from a dry sand to a saturated clay, and both of these will be changed by rainfall.

Figs. 1 to 6 present apparent resistivity curves to show the effect of a variable surface layer. In all cases resistivity varies linearly with depth down to a depth of one unit. Material beneath this depth has constant resistivity. Electrode separation is plotted in depth units. Insets on each figure show the corresponding cross-sections, plotting true resistivity against depth.

To illustrate, consider curve *A* of Fig. 1. The true resistivity of material at the surface of the earth is taken as 0.4 units. Resistivity increases with depth, reaching a value of 1.0 at 0.5 depth units and 1.6 at 1.0 depth units. Below a depth of 1.0, all the material has very low resistivity (zero, for purposes of calculation). Curve *A* in the main part of Fig. 1 shows how apparent resistivity varies for this case as the electrode spacing is increased. To illustrate further, curve *E* of Fig. 4 corresponds to true resistivity of 1.2 units at the surface, 1.0 at a depth of 0.5 units, 0.8 at a depth of 1.0, and 1.5 for all depths greater than 1.0.

Apparent resistivity curves have been plotted logarithmically so that the shape of the curves becomes independent of the units, giving the curves wide validity. A certain drift-covered area, for example, shows a gradual decrease of resistivity from 230 ohm-meters at the surface to 150 ohm-meters at the bedrock surface, 275 ft down; bedrock resistivity is 800 ohm-meters. Curve *E* of Fig. 5 indicates that true resistivity decreases from 1.2 units at the surface to 0.8 at a depth of 1.0, then increases abruptly to a constant value of 4.0 units. Since resistivity and depth ratios are the same, this can be used to predict the field curve. For Fig. 5, multiply true resistivity and apparent resistivity by

H. M. MOONEY is Assistant Professor of Geophysics, University of Minnesota, Minneapolis, Minn.

Discussion on this paper, TP 3900L, may be sent (2 copies) to AIME before Jan. 31, 1954. Manuscript, March 29, 1954.

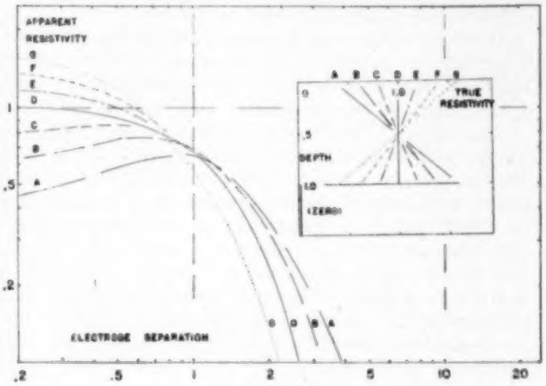


Fig. 1

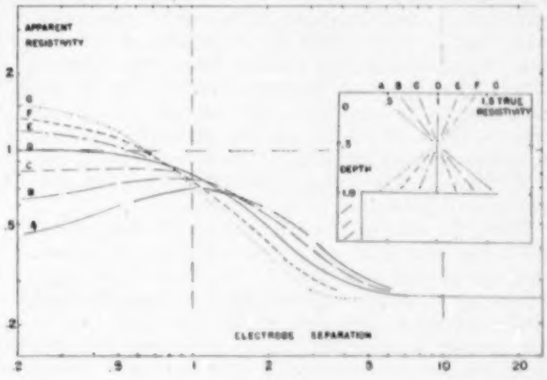


Fig. 2

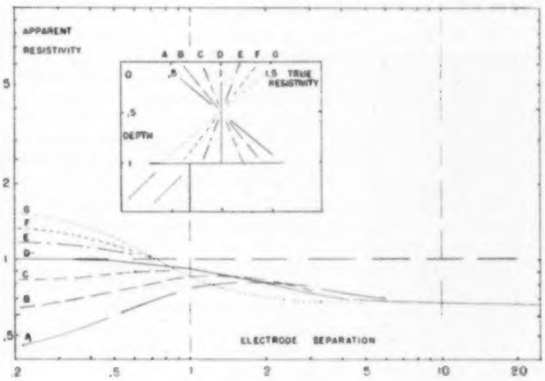


Fig. 3

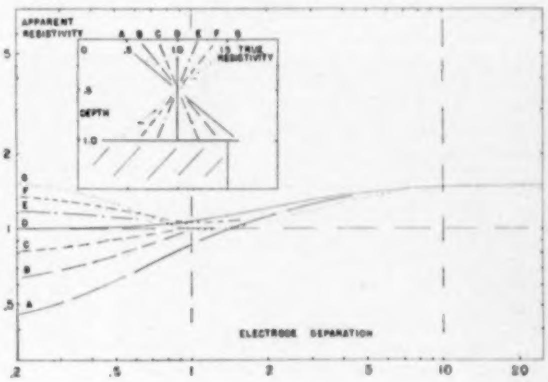


Fig. 4

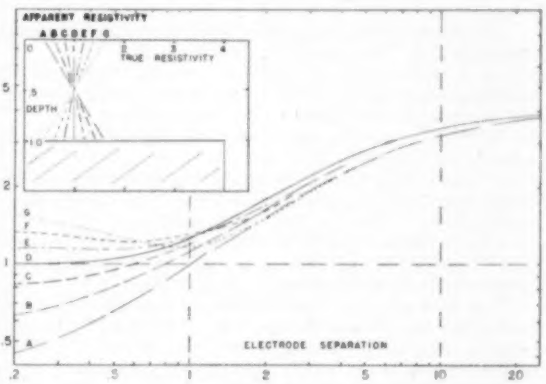


Fig. 5

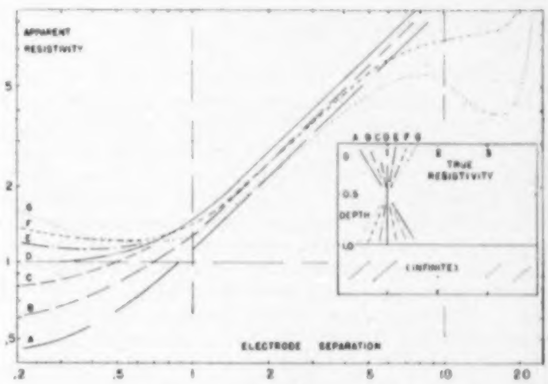


Fig. 6

Figs. 1-6 (reading across from upper left to lower right)—Apparent resistivity curves show the effect of a variable surface layer. In all cases resistivity varies linearly with depth. Material beneath this depth has constant resistivity. Electrode separation is plotted in depth units. Insets on each figure show the corresponding cross-sections, plotting true resistivity against depth.

230/1.2, labeling the new units ohm-meters; multiply depth and electrode separation by 275/1.0, labeling the new units feet. Curve E approximates the apparent resistivity data.

The preceding example used known geology to predict an apparent resistivity curve. The more usual situation, of course, is to infer geology from field data.

Curve D in all the figures represents the usual two-layer case of constant resistivity in the surface layer. This serves as a basis for comparison.

For those who wish a mathematical description of the curves, resistivity in the surface layer has been represented in the form $P_1 = K_1 + K_2Z$, where Z is depth and K's are constants. Curves A, B, C, etc. correspond to $(K_1, K_2) = (0.4, 1.2), (0.6, 0.8), (0.8, 0.4), (1.0, 0.0), (1.2, -0.4), (1.4, -0.8)$, and $(1.6, -1.2)$. These particular combinations were chosen so that the average resistivity of the surface layer would be the same in all cases, namely 1.0. Figs. 1, 2, 3, etc. correspond to lower layer resistivities of 0, 1/4, 2/3, 3/2, 4, and infinity.

Calculations were carried out incidental to a larger project for computing four-layer curves; the mathematics will be described in the report of this project.[14] In summary, the surface layer was approximated by a series of five thin layers, each of constant resistivity. Surface potentials were evaluated with an electronic computer by numerical integration of an infinite integral. Although a general solution of this problem would be impossibly long, symmetry here permitted simplification.

When the curves are compared with the constant resistivity result in each figure (curve *D*), several conclusions may be drawn: 1—The major effect occurs for electrode separations less than the depth of the interface, i.e., separations less than 1.0. 2—For smaller separations, the curves asymptotically approach the true resistivity at the surface. 3—For larger separations, the deviation exceeds 10 pct only in severe cases. 4—For *high* resistivity in the lower layer, Figs. 4 to 6, *all* curves lie below curve *D* for larger electrode separations. 5—For *low* resistivity in the lower layer, Figs. 1 to 3, *all* curves cross curve *D*. 6—As would be expected, all curves are asymptotic to curve *D* for large separations, but this behavior is less apparent for high than for low resistivity in the lower layer.

Table I. Errors in Interpretation of Field Curves

Resistivity	P_1	Depth
Low resistivity in second layer, Figs. 1-3; increasing resistivity with depth, curves *A-C*	Too low	Too high
Low resistivity in second layer, Figs. 1-3; decreasing resistivity with depth, curves *E-G*	Too high	Too low
High resistivity in second layer, Figs. 4-6; increasing resistivity with depth, curves *A-C*	Too low	Too low
High resistivity in second layer, Figs. 4-6; decreasing resistivity with depth, curves *E-G*	Too high	Too high

For the larger electrode separations curves *F* and *G* of Fig. 6 show an effect of some mathematical interest. Inspection of the inset will show that for these cases resistivity drops to a very low value within the lower layer. In a slightly more extreme case, a thin perfect conductor can be imagined lying just above a thin perfect insulator. The presence of the insulator could then not be detected; the apparent resistivity curve would look something like *G* in Fig. 1. The beginnings of this tendency can be seen in curves *F* and *G* of Fig. 6. The phenomenon has no practical importance, since such extreme resistivity contrasts are most improbable geologically.

An interpreter faced with field curves of the sort shown in Figs. 1 to 6 might attempt to interpret them by matching to two-layer curves. His results would be in error as shown in Table I.

In all cases the matches are poor enough to arouse suspicion. A given field curve can be placed by inspection in one of the four categories given in Table I; directions of the suspected error are then known.

The curves of Figs. 1 to 6 could also be interpreted as three-layer problems; some provide a fairly good match. The trend here cannot be specified so well, for it will depend on the interpreter's judgment as to which match is most plausible. Experience shows that the depths are usually too low and that the interpreted surface resistivity approaches the true surface resistivity. This serious possibility for misinterpretation serves to emphasize a general rule for resistivity work: every area presents its own problems and requires careful preliminary work at control points before a field program can be attempted.

References

[1] H. M. Mooney: Depth Determinations by Electrical Resistivity. *Trans.* AIME (September 1954) **199**, p. 915.

[2] W. Stern: Resistivity Methods for Investigation of Tectonics and Underground Hydrology. *Beitr. Ang. Geoph.* (1933) **3**, p. 408. In German.

[3] R. F. Aldredge: The Effect of Dipping Strata on Earth Resistivity Determinations. *Colorado School of Mines Quarterly* (1937) **32**, p. 171.

[4] R. Trudu: Resistivity Curves for Two Layers with Plane Contact Slightly Inclined. *Riv. Geof. Appl.* (1952) **13**, p. 95. In Italian.

[5] T. Y. Berel'kovskiy and B. G. Zubanov: The Determination of an Inclined Contact by the Electrical Method. *Akad. Nauk. SSSR Izv. Ser. Geofiz.* (1951) **3**, p. 16. (Geophysical Abstracts 150, 13950). In Russian.

[6] M. Unz: Apparent Resistivity Curves for Dipping Beds. *Geophysics* (1953) **18**, p. 116.

[7] L. Cagniard: The Importance of the Phenomenon of Anisotropy in Electrical Sounding. *Inst. Phys. Globe Strasbourg Ann.* (1948) **4**, p. 3. In French.

[8] R. Maillet: Fundamental Equations of Electrical Prospecting. *Geophysics* (1947) **12**, p. 529.

[9] S. J. Pirson: Effect of Anisotropy on Apparent Resistivity Curves. *Bulletin of the American Association of Petroleum Geologists* (1935) **19**, p. 35.

[10] A. Belluigi: On the Effect of Anisotropy. *Beitr. Ang. Geoph.* (1934) **4**, p. 400. In German.

[11] R. Geneslay and F. Rouget: On Electrical Anisotropy and Pseudo-Anisotropy. *Proc.* 2me Cong. Mond. Petr., Paris (1937), p. 723. In French.

[12] W. G. Keck and W. F. Colby: The Depth Dependence of Earth Conductivity on Surface Potential Data. *Journal of Applied Physics* (1942) **13**, p. 17.

[13] A. F. Stevenson: On the Theoretical Determination of Earth Resistance from Surface Potential Measurements. *Physics* (1934) **5**, p. 114.

[14] H. M. Mooney and W. W. Wetzel: *Potentials about a Point Electrode and Apparent Resistivity Curves for a Four-Layered Earth.* Scheduled for 1955 publication, University of Minnesota Press.

ABSTRACT

Principles of fluid motion and turbulence which have been found to be of use in mixing and agitation problems are discussed, as well as suggested applications in extractive-metallurgy processes. Various types of impellers are described, together with other conditions that affect flow pattern and turbulence. The choice of equipment for particular requirements is considered, and equations for power input are given. Modern heavy-duty mixing and agitation equipment can take an increasingly important part in such extractive-metallurgy processes as solids handling, crystallizing and leaching, chemical operations, and flotation. Application of mixing and fluid-mechanics principles to extraction methods can lead to greater process rates and a resultant saving in time and money.

The article from which the above abstract is reprinted, *Fundamentals of Mixing and Agitation with Applications to Extractive Metallurgy*, by J. H. Rushton and L. H. Mahony, appears on pp. 1199-1206 of JOURNAL OF METALS, November 1954.

First Rocky Mountain Industrial Minerals Conference a Success

The success of the Rocky Mountain Industrial Minerals Conference at Salt Lake City, October 29 and 30, has the Utah Section looking forward to the second edition scheduled for Oct. 6 to 8, 1955.

Some 231 persons registered for the meeting. Turnout was large all the way down the line with 218 attending the luncheon, 300 at the dinner-dance, and 183 taking in the Idaho-Utah football game.

Friday morning technical sessions featured steel, industrial water and nonmetallics. ElRoy Nelson, vice president, First Security Corp., delivered his paper on *Industrial Water*, John K. Hayes, U. S. Steel Corp. spoke on *The Role of Industrial Minerals in Utah's Steel Industry*, H. F. Hillard, Mountain Fuel Supply Co., discussed *Natural Gas in the Intermountain Area*, and C. A. Romano described *Chemical Treatment of Ores*, during the first technical session.

During the afternoon registrants heard that there is no leveling off in sight for the growing phosphate mining industry in Utah, Idaho, and southern Wyoming. Charles W. Sweetwood told his audience that "During 1953, more than 2 million tons of phosphate rock and shale were mined and shipped for processing into fertilizers and elemental phosphorus . . .

"To supply these demands, as well as an increase in domestic consumption, many millions of tons of reserves remain available for mining within this Intermountain Area.

"Such mining cannot be carried out haphazardly, however. . . . In addition, vanadium and possibly uranium may eventually be recovered economically from within the phosphoria formation."

He continued, "The area . . . will undoubtedly become the phosphate center of the U. S."

W. P. Dunlap, delivering a paper prepared by J. L. Whiteside, Monsanto Chemical Co. plant manager, noted that Monsanto mined and stockpiled 350,000 tons of ore during this year for reduction to elemental phosphorus in furnaces at Soda Springs, Idaho.

The technical sessions attracted a great many people. Typical of the gatherings was this one that assembled to hear papers following the luncheon.

C. C. Blalock, Colorado Fuel & Iron Corp., noted that the Soviet Union has evinced a tremendous interest in titanium as exhibited by the publication of some 257 technical articles on metallurgy and processing of the metal. Although most of the literature dealt with laboratory stages of development, it is assumed that some titanium is being produced behind the Iron Curtain. Mr. Blalock estimated 1954 titanium production in the U. S. to be about 5000 tons compared with 3 tons in 1948.

John A. Wolfe of the Ideal Cement Co. spoke on *Economic and Chemical Aspects of Cement Raw Materials*, and D. A. Power of Westvaco rounded out the afternoon session with his paper on barite.

Saturday morning Marvin L. Kay, vice president and general manager of Climax Uranium Co. said, during his time on the rostrum, "One of the outstanding factors influencing the uranium business is the tremendous growth of the 'penny stock' companies. I have been told by a gentleman in the trade that the amount of such issues is $66 million. And the amount continues to grow.

"This indicates a tremendous public interest in the uranium industry and provides a means for the mining industry to raise 'risk' capital for the exploration of ore. But the industry itself should see that this privilege is not abused. Of course, it should be the responsibility of the investor to analyze what stock he is purchasing. But, as P. T. Barnum has said, 'a sucker is born every minute.'"

It was Mr. Kay's opinion that penny stocks are manifestations of growing pains. However, that the "suckers" must be protected from "unscrupulous promoters."

Mr. Kay, in his talk, noted that the basic problems facing uranium mine development on the Colorado Plateau were:

Necessity of enforcement of present federal laws as to staking claims, defining boundaries, and tying claims to permanent monuments.

Need for amending mining laws of 1872 so that valid location of minerals in sedimentary orebodies can be made.

Clarification and enforcement of present assessment laws with added provision whereby assessment work can be filed in the county of claim location. Assessment work should be recorded and detailed for ready checking.

Continuing the Saturday session, Sid Eliason, president of Western Gypsum Co., presented the paper, *Gypsum in Utah* prepared by W. S. Mole of the same firm. *What about Gilsonite?* was the topic of a paper by Park L. Morse, American Gilsonite Co.

(Continued on p. 1217)

Annual Meeting — Chicago, U. S. A.

Program Data As of Nov. 15, 1954

The calendar is running full tilt toward Annual Meeting time, February 14 to 17 at Chicago's Conrad Hilton Hotel. Program committee activity has reached an intense stage. Most of the groundwork for what promises to be one of the greatest meetings in Institute history has been completed.

Industrial Minerals

Technical session alignment is nearing the completion stage, with some groups reporting the task almost finished. The Industrial Minerals Div. program is almost finalized.

The Cement, Lime, and Gypsum session papers include: *Raw Material Preparation at the Brandon, Miss., Cement Plant*, by J. C. Holm; *Conservation of Lime and Recovery of Lime in Sulphate Pulp Mills*, by W. Tock; *Human Response to Industrial Blasting Vibrations*, by Jules E. Jenkins; *The New Thornton Dolomite Plant*, by Lee H. Niems; and *Quarry Operation, with Emphasis on Heavy Stripping*, by National Gypsum Co.

The Ceramic Raw Materials session will have: *Staurolite—New Industrial Mineral*, by C. H. Evans; *The Synthesis and Properties of Large Crystals of Strontium Titanate*, by Leon Merker; *Geology and Ceramic Properties of Hydrothermally Altered Volcanic Rocks of California*, by Oliver Bowen, Jr., and Melvin G. Stinson; *Reserves of Missouri Diaspore, Flint, and Semi-Plastic Clay*, by F. G. Mertens; and a movie on bentonite production, with commentary by A. G. Clem.

Oscar M. Wicken is expected to be the Chairman of the Chemical Raw Materials session. Papers on the agenda are: *Genesis of Appalachian Limestones and Dolomites, and its Bearing on Their Industrial Uses*, by Byron M. Cooper; *Mexican Sulphur Developments*, by Harold H. Jacquet; *Uranium From the Florida Leached Zone*, by James A. Barr, Jr.; *The Future of Industrial Limestone Production in the Midwest*, by Kenneth A. Gutschick and J. P. Flynn; and *The Barite Industry*, by Byron C. Elsley.

The Dimension Stone and Slate session will feature a round-table discussion.

Papers to be presented under the heading of Fillers, Fibers, and Pigments are: *The Fuller's Earth Industry in the Florida-Georgia District*, by James L. Calver; *Pigments—A General Survey, with Special Reference to Titania*, by L. R. Blair; *Barite as a Filler for Rubber in Roads and in Asphalt*, by Walter F. Winters; *Ball Clay Mining*, by Richard Bell; *Processing and Specifications of Kaolin for Use as Paper Coater and Filter*, by C. G. Albert; and *Quality Control of the New Non-Metallic Pigment, Wollastonite*, by C. H. Pratt.

Mineral Aggregate papers will be: *Aggregates for Jet and Rocket Runways*, by Robert Barnett; *Production Problems of the Stone Industry and Needed Research*, by Nelson Severinghaus; and *Heavy Burned Clay Aggregates*, by Norman Plummer.

In the category of Special Sands and Abrasives, papers are expected to include: *New Developments in Silica Sands and Abrasives in the Southern Mid-Continent Region*, by William E. Ham; *Eastern Bonded Sands*, by Robert J. Maddison; and *Flotation of Del Monte Sands*, by William E. Messner and Hugh H. Bein.

Rare Minerals will have *That Atom—Lithium* by L. G. Bliss; *Lithium Resources of the United States*, by J. J. Norton; *Spodumene Mining in the Black Hills*, by Fremont Clarke; and *Chemical Processing of Lithium Ores*, by Reuben Ellestad.

Industrial Waters papers will deal with: *The Relationship of Industrial Waste and Industrial Water Problems in California*, by V. W. Bacon; *Water Specifications and Water Quality*, by John E. Tarman, W. H. Betz, and L. D. Betz; *Groundwater Geology in Industrial Expansion and Decentralization*, by John W. Foster; *Uses and Abuses of Mineralized Ground Water*, by Walter O. George; *Status of Research on Stream Pollution Control*, by W. B. Hart; *Demineralization of Brackish Waters by the Electric Membrane Method*, by Thomas A. Kirkham; and *Evaluation of Rainmaking and Weather Modification Techniques*, by H. T. Orville.

Coal

According to a preliminary program submitted by the Coal Div., papers under Coal Preparation—Flotation will be: *Effect of Flocculents on Coal Sedimentation*, by S. C. Sun; *Possibility of Increasing Coal Flotation Cell Capacities as Indicated in Semi-Commercial Scale Experiments*, by B. W. Gandrud and H. L. Riley; and *Flotation of High-Sulphur Coal*, by S. C. Sun, W. L. Deppe, and A. Davidson.

Another set of Coal Preparation papers will be: *The Main Qualities of a Good Installation of Coal Preparation*, by L. Mohier; and *The Application of the Vacuum Filter in the Coal Washing Circuit*, by J. Apotheker, C. E. Silverblatt, and D. A. Dahlstrom.

A session on Utilization—Carbonization will feature: *Low-Temperature Carbonization of Lignite and Non-Coking Coals in the Entrained State*, by V. F. Parry, E. O. Wagner, and W. S. Landers; and two others dealing with coal gasification and low temperature carbonization. The former will be presented by E. S. Pettyjohn, and the latter by C. E. Lesher.

Stream and Air Pollution will deal with: *Application and Economics of Slime Removal for Closed Water Circuits*, by D. A. Dahlstrom; *Sealing Mine Refuse Piles with Refuse Fines*, by E. G. Graf, G. T. Mazie, and J. W. Myers; and *Truth and Fallacy Regarding Acid Coal Mine Drainage*, by S. A. Braley.

Two Underground Mining sessions will have: *A Study of Problems Encountered in Multiple-Seam Coal Mining*, by David T. Stemple; *A Preliminary Report on Underclay Squeezes in Coal Mines*, by W. Arthur White; *Power Lighting Underground*, by Gerald von Stroh; and *Operation of Dry Dust Collectors on Rotary Roof Bolt Drilling Equipment*, by J. S. Whittaker.

Mining

Plans are almost complete for the Mining, Geology, and Geophysics Div. part in the Annual Meeting. The Mining Subdivision has scheduled, under the heading of Small Mines Problems, the following: *Banner Mining Co.*, by Allan Bowman; *Phosphate Mining, Idaho*, by D. L. King; *Chrome Mining in Montana*, by John Bley; and *Types of Mining in the Uranium Fields of the Colorado Plateau*, by B. E. Grant.

Papers scheduled for the Open Pit Mining session are: *The Three R's of Open Pit Mining—Repairs, Replacements, and Results*, by V. E. Fielding; *What is the Economic Point of Replacement of Pit Equipment in the Southwest?*, by B. R. Coil and J. W. Still; *Freeze Proofing Methods Employed at the Utah Copper Pit*, by J. C. Landenberger, Jr.; and *Overburden Removal Methods, Demerara Bauxite Co., British Guiana*, by R. E. Sinke.

Stratified Mining papers include: *Work at Rifle, Colorado*, by a U. S. Bureau of Mines author; *Strain Gauges and Roof Bolting*, by Mr. Romano; and *Blasting Research Leads to New Theories and Large Reductions in Blasting Costs*, by Boris Kochanowsky.

Those expected to deliver papers for the Mining Research session are: E. R. Borcherdt, J. D. Forrester, and Leonard Obert.

Jackleg Drilling in the Tri-State District, by S. S. Clarke will lead off the Drilling Problems session. Other papers are *Progress in the Use of*

Jet Piercing in a Massachusetts Granite Quarry, by Ralph Fletcher; and *Exhaust Dust Control with Dry Percussion Drilling*, by E. P. Pfleider.

Friction Drive Mine Hoists, by E. P. Pfleider, E. G. Malmlow, and F. Landau; and *Mine Safety*, by John J. Reed, will take up another session.

Geology

The Uranium session of the Geology Subdivision will cover: *Uranium Genesis*, by T. W. Mitcham; *Uranium Occurrences in the Eastern U. S.*, by Thomas Walthier; *Recent Uranium Developments in Ontario*, by J. D. Bateman; and *Uranium Deposits in the Black Hills*, by John W. King.

Two papers are already certain for the joint session of the Geology Subdivision and the Society of Economic Geologists. They are: *Exploration of Riddle Mountain Nickel Deposits*, by A. E. Walker; and *Anticlinal Control of Ore Deposition*, by Dooley P. Wheeler. Two other papers are being prepared.

Papers for the joint session with the Geophysics Subdivision are slated to be: *The Inductive Electromagnetic Method as Applied to Iron Ore*, by S. Ward; a geology-geophysics paper by H. V. Scott; *Geophysical Case History of Marmora Mine*, by W. G. Wahl and S. Lake; *Geochemical Prospecting in Nyeba District, Nigeria*, by H. E. Hawkes; and the *Results and Interpretation of a Ground and Helicopter Survey of Green Pond, Morris County, New Jersey*, by W. B. Agocs.

Under the heading of Mineral Resources are papers titled: *Mineral Resources of the Southeastern States*, by Robert A. Laurence; *Future Mineral Resources of Arizona and Nevada*, by W. W. Simmons; *Latent Mineral Wealth in the Pacific Northwest*, by Ralph Watson; and *Future Mineral Possibilities of the Central Rocky Mountain Region*, by M. Kildale.

Exploration session papers are reported to be: *Geological Exploration in Canada's Far North*, by W. O. Fortier; *Helicopter Prospecting in Yukon Territory*, by P. A. Peach; *Brazil's Mineral Future*, by W. D. Johnston; and *Philippine Industrial Minerals*, by Consorcio G. Roa.

A joint session with the Geophysics Subdivision on Iron Ore Exploration will tentatively include two papers for morning presentation and a panel discussion in the afternoon.

Other papers to be read will be: *Mineralogenic Epochs and Mineralogenic Provinces*, by Charles H. Behre, Jr.; *Collapse Features at Temple Mountain, Utah*, by P. F. Kerr; *Gravimetric Mapping*, by H. Seigel; and *A New Method of Evaluating Diamond Drill Core Sludge Samples at Chuquicamata*, by Glenn C. Waterman.

Geophysics

Hans Lundberg will read his paper, *Airborne Geophysical Methods—Electromagnetic, Radioactive, and Magnetic*, at a Geophysics Subdivision meeting.

In addition to the joint session scheduled with the Geology Subdivision, the Geophysics Subdivision will hold another with the Industrial Minerals Div. Subjects to be investigated are: *General Developments in the Lithium Industry*, by Felix Shay; *Lithium Resources of the United States*, by J. J. Norton; *Results of Geological Work in the Tin Spodumene Belt of North Carolina*, by W. R. Griffiths; *Spodumene Mining in the Black Hills*, by Fremont Clark; and *Chemical Processing of Lithium Ores*, by Reuben Ellestad.

The Mining, Geology, and Geophysics Subdivision Luncheon, will again feature the presentation of the Daniel C. Jackling Award. The 1955 recipient is E. D. Gardner, formerly chief mining engineer, U. S. Bureau of Mines, now retired. Later, the division will meet to hear Mr. Gardner deliver the Jackling Lecture. Another paper, *Development and Application of the Small Diameter Wire Line Core Barrel*, by V. N. Burnhart, is also on the agenda.

Minerals Beneficiation

The list of papers to be presented by the Minerals Beneficiation Div., now almost in final form, includes: *Designing Ore Treatment Pilot Plants*, by R. D. MacDonald and F. M. Stephens; *Design of Tubular Conveyor Galleries*, by H. L. Tamplin, D. E. Bourke, and L. Ratnik; *Layout of Grinding Floors*, by a representative of Mine & Smelter Supply Co.; *Drafting, Construction Models, and Visual Aids*, by Frank P. Pettit; *Metal Precipitation from Salt Solution by H_2 Reduction*, by F. A. Schaufelberger; *Nickel-Cobalt Separation by Selective Reduction*, by F. A. Schaufelberger and T. K. Roy; *The Beaverlodge Hydrometallurgical Plant*, by R. W. Mancantelli and J. R. Woodward.

Power Correlation for Rod Mills, by P. K. Guerrero and N. Arbiter; *Correlation Between Principal Parameters Affecting Mechanical Ball Wear*, by H. T. Hukki; *Tumbling Mill Capacity and Power Consumption as Related to Mill Speed*, by H. T. Hukki; *Analysis of Rod Milling Variables—Comparison of Overflow and End Peripheral Discharge Mills*, by Will Mitchell, Jr., C. L. Sollenberger, T. G. Kirkland, and B. H. Bergstrom.

Comminution Calculations, by F. C. Bond; *Rapid Method to Rate Reduction Ratios from Screen Analyses*, by A. Legsdin and F. L. Schenck; *Ore Sampling—Art or Science*, by S. L. Smith and B. H. Irwin; *The Gravity Flow of Bulk Solids*, by Norman F. Schultz; *Handling Difficult Flotation Froths*, by W. H. Reck; *Flocculation of Mineral Suspensions with Coprecipitated Polyelectrolytes*, by M. E. Wadsworth and I. B. Cutler; *Theory and Application of Polyelectrolytes to Flocculation*, by R. A. Ruehrwein; *Use of Surface Active Agents in Filtration of Flotation Concentrates*, by S. C. Sun, D. R. Mitchell, and W. L. Deppe.

The Eimco-Burwell Filter, by R. B. Thompson and D. A. Dahlstrom; *Iron Ore Flotation at Humboldt*, by Richard R. Smith; *Climax Milling Methods*, by M. W. Dessau and F. J. Windolph; *The Development of Metallurgical Practices at Tsumeb*, by J. P. Ratledge, J. H. Boyce, and J. N. Ong; *Quantitative Use of X-ray Diffraction for Analysis of Iron Oxides in Gogebic Taconite of Wisconsin*, by R. S. Shoemaker and D. L. Harris; *Microscopic Identification and Mineral Analysis*, by B. H. McLeod.

An Agglomeration Process for Iron Ore Concentrates, by W. F. Stowasser; *Desliming and Preliminary Concentration of Ores with Ultrasonics*, by S. C. Sun and D. R. Mitchell; *The Effect of Impeller Speed and Air Volume on the Flotation Rate*, by W. E. Horst and T. M. Morris; *Depolarizing of Magnetite Pulps*, by L. G. Hendrickson and M. F. Williams; *Types of Commercial Wet Magnetic Separators and Their Application to Mineral Dressing*, by T. K. Maki and E. Furness; *Substituted Starches in Amine Flotation of Iron Ore*, by C. S. Chang; *Adsorption of Dodecylammonium Acetate on Hematite and its Flotation Effect*, by A. M. Gaudin and J. G. Morrow; *Flotation and the Gibbs Adsorption Equation*, by P. L. deBruyn, J. Th. G. Overbeek, and R. Schuhmann, Jr.

Some Physico Chemical Aspects of Flotation, by C. C. DeWitt; *Streaming Potential Studies—Quartz Flotation with Anionic Collectors*, by A. M. Gaudin and D. W. Fuerstenau; *Flotation of Quartz by Cationic Collectors—Adsorption Studies at the Liquid-Solid Interface*, by P. L. deBruyn; *Adsorption of a Mercaptan on Zinc Minerals*, by A. M. Gaudin and D. L. Harris.

Problems in Flotation Rate Studies, by N. Arbiter; and *Some Pitfalls in Dust Control in Ore Conditioning and Crushing Plants*, by R. T. Wilson.

The symposium, *Planning a Successful Ore Beneficiation Plant*, will review the following subjects: What information should the metallurgical engineer obtain from the geology and mining departments to do a good job of testing? by S. R. Zimmerley; What information should the metallurgical engineer give the mill designer? by Frank Briber and Jess Carlile; What is the responsibility of the equipment manufacturer in mill design? by Kellogg Krebs; What does the operator expect of the research department on metallurgical and of the mill designer on design? by W. A. Hamilton and O. M. Wicken; Some suggestions on how the operator, mill designer, metallurgical engineer, and contractor can work together, by C. Marsh; and A good construction contract, by R. A. Blake.

Lake Placid Proves Ideal Setting For Industrial Minerals Fall Meeting

by C. M. Cooley

Seated at the head table during the Farewell Banquet at the end of the Industrial Minerals Div. Fall Meeting were from left to right: John G. Broughton; R. C. Stephenson, Chairman, Industrial Minerals Div.; M. F. Goudge, guest speaker from the Canadian Dept. of Mines and Technical Surveys; Paul Allen, Chairman, Adirondack Section; Carlisle Gerow, Secretary, Canadian Institute of Mining and Metallurgy, and Sanford S. Cole. Others seated at the head table but not shown were: Felix Shay, R. M. Grogan, and C. M. Cooley.

Brisk mountain air, flame-colored leaves, and fantastic scenery contributed to what many members attending the 1954 Fall Meeting of the Industrial Minerals Div. considered one of the best seasonal conclaves of the AIME in many years.

Driving, walking, or just plain relaxing amidst the full-bosomed finery of Lake Placid autumn when the more serious business of technical discussion was finished proved to be an exciting experience.

The informal gathering in the dining room of the Whiteface Inn following registration, gave members of the division a chance to get into the mood. The dance floor was open and the music good. But the following day registrants buckled down to the business at hand—with the entire day devoted to technical sessions. Six papers were presented.

Matt S. Walton, Jr.'s discussion of the geological setting of the Adirondack ore deposits brought to light some interesting features. One of the items he paid special attention to was that "The Adirondack region consists of a complex of pre-Cambrian igneous and sedimentary rocks all of which, with minor exceptions, had been subjected to intense deformation and strong to extreme regional metamorphism."

Upper New York State mining had its time in the spotlight when John A. Graham discussed the mineral industry of the Adirondacks with the accent on various metallics. Mr. Graham pointed out that "The value of New York State's mineral resources in 1952 was $190 million. Mining and quarrying in the Adirondacks contributed almost 30 pct of the total. New York is the leading U. S. producer of magnetite, ilmenite, talc, garnet, and wollastonite. All those minerals are produced in the Adirondacks."

When the technical session broke for lunch, discussion moved from meeting room to dining room.

When the technical program got underway once more John G. Broughton led off by explaining the use of anorthosite as an industrial mineral. He listed large deposits of the mineral in New York State. Mr. Broughton noted that "Private and governmental research indicates that the rock itself constitutes a raw material for alumina, with calcium trisilicate for portland cement as a by-product, if it becomes possible to lower treatment costs to a competitive position . . . Other uses of anorthosite include building stone, chemical process tanks, and the manufacture of highly refractory ceramic bodies."

F. G. Kuehl described operations of the International Talc Co. at Gouveneur, N. Y., filling in details on location, history, geology, mining, milling, and labor at the firm's various plants. Roger N. Miller was the co-author of this paper.

Continuing with the theme of the Mineral Industries of the Adirondacks, LeRoy Scharon described geophysical prospecting for ilmenite in the Adirondacks based on his experience in past years. He disclosed that "the magnetic method has been employed successfully in the Adirondacks for finding titanium bearing ores."

At the technical session Thursday morning, J. L. Gillson described the genesis of the titaniferous magnetites of the Lake Sanford district. He advanced a theory that the "Whiteface anorthosite, gabbro, and ore resulted from the long continuous action of solutions passing through an already solid rock. These solutions at first were rich only in soda, becoming progressively richer in iron and titanium. The Whiteface anorthosite, gabbro, and ore are replacement bodies instead of differentiates."

Ray Ladoo, active in the development of wollastonite as a new industrial mineral, presented additional information on wollastonite and diopside for industrial applications in the session Thursday morning. He briefly described the Willsboro, N. Y., wollastonite and diopside, along with notes on milling and research.

D. M. Larrabee next offered his *Commercial Colored Slates of New York and Vermont*, which was followed by Lester W. Strock's *Geochemistry and Importance of Saratoga Mineral Waters.*

Coming on the heels of Mr. Strock's paper was one by C. H. Pratt outlining quality control and crushing and grinding of wollastonite. He stated "that commercial production of this nonmetallic mineral has started at the Godfrey L. Cabot Co. It's being used for ceramics, paint, and several other applications." Mr. Pratt delved into the development of adequate plant control tests with special attention to standardization.

Thursday afternoon saw conferees making the trek to the Cabot Minerals Div. wollastonite plant at Willsboro. Snow the night before spread over the land — making coffee arranged for by the local section a highly desired item and a reason for many thanks. The afternoon was spent inspecting the open pit and mill.

Canadian industrial minerals held the interest of those who attended the Friday technical session. Norman B. Davis outlined the industrial minerals of the Ottawa Valley. Briefly, he told of the use of water for industrial power and of the deposits of graphite, magnetite, feldspar, mica, apatite, brucitic limestone, dolomite, limestone, sandstone, sands, and gravels that have been produced in important quantities in the past or are in current production.

J. W. Craig recounted some of the problems and developments in the manufacture of basic brick in Canada.

Later that morning the Executive Committee of the Industrial Minerals Div. met to arrange plans for

the forthcoming Annual Meeting in Chicago.

The clang of horseshoes hitting the stake, crashing of bowling pins, and the clean click of driver against ball filled the air Friday afternoon. Eagle eyes lined up long putts and sank them, and shuffleboard artists slid shuffleboard disks along the ground with bullet-like accuracy. Prizes were awarded for first and last places, with ladies and men competing hard for the baubles.

Another social hour was held before the farewell banquet. M. F. Goudge, chief of the Industrial Minerals Div. of the Canadian Dept. of Mines & Technical Surveys, in his role of guest speaker, discussed industrial minerals in Canada. R. C. Stephenson, Chairman of the Industrial Minerals Div., presented a resolution of appreciation directed at the Adirondack Section for the excellent meeting and to the various firms who contributed to its success.

Entertainment for the evening turned out to be rather spontaneous—and derived from home talent. Most of those who contributed to the laugh-provoking situation high jinks were from the local section, with a fair sprinkling of others chiming in.

Among the feats of strength, skill, and perseverance division members and their wives were called upon to perform, was one where both members of a team had to maneuver an inner tube around themselves and then switch floor positions with the other couple.

Another contest called for blindfolds to be placed over the eyes of the distaff side. It was up to them to then identify the legs of their husbands by the sense of touch.

Field trips on Saturday morning saw most of the conferees up with the sun—or almost. Parties left for individual Adirondack destinations and then left for the trek homeward.

A lot of people put monumental amounts of time and effort into making the Fall Meeting a real smash. Adirondack Section committee members were: Paul Allen, John G. Hall, Archie McDonnell, Ed Sullivan, R. M. McClellen, Arthur Hall, Mrs. Arthur Hall, and Charles Dievendorf.

Division committee for the 1954 Fall Meeting consisted of: John G. Broughton, Chairman; Paul W. Allen, C. M. Cooley, R. M. Grogan, and R. B. Ladoo.

Suppliers who contributed to the success of the gathering were: D. Cohen & Sons; Carbola Chemical Co.; Tri-State Electric Co.; Hulbert Bros.; V. Jerry & Sons; Charles T. Main Co.; Du Pont de Nemours Corp.; National Lead Co.; L. B. Smith; Newton Falls Paper Mill; Eimco; Cabot Minerals; Exolon Co.; New York Explosives Co.; Republic Steel Co.; Bucyrus-Erie Co.; Koert Burnham; Mine Safety Appliances Co.; Allis-Chalmers Mfg. Co.; Baldwin-Hall Co.; John Weekes & Son; Langdon & Hughes Electric Co.; Bill Breed; Syracuse Sales Co.; Thos. H. Bradley Co.; Contractors Sales Co.; American Manganese Steel Co.; Burns Piping Supply Co.; Socony Vacuum Co.; and one who wished to be anonymous.

Rocky Mountain Conference

(Continued from p. 1213)

On the list of social events the luncheon on Friday with H. DeWitt Smith, President-elect of the AIME for 1955, as the featured speaker was a top attraction. Mr. Smith traced the growth of Kennecott Copper Corp. from the company's beginning as a small Alaskan copper mine. By the time the Alaskan venture started to decline, the company was involved in low grade ore in the U. S. having purchased an interest in Utah Copper Co. Purchase of 95 pct gave them control of a Chilean orebody.

One of the highlights of the conference was the 70th anniversary of the Eimco Corp.

Saturday afternoon, conferees took in the University of Utah vs University of Idaho football game at Salt Lake City. It was a hard-fought, well-played game, with Idaho winning 14 to 13.

Another social function was the special luncheon meeting held by the WAAIME in honor of Mrs. Smith and Mrs. E. H. Robie. Mr. and Mrs. Robie attended the conference as guests of the Utah Section as did Mr. and Mrs. Smith.

The conference wound up with the Utah Section's annual fall cocktail party and dinner-dance at the Hotel Newhouse, meeting headquarters. With plans already afoot for next year's conference, it is reported that the Minerals Beneficiation Div. has accepted the invitation of the Utah Section to hold its annual meeting at the same time.

Responsible for organizing the program this year were: W. F. Rappold, Vice Chairman, Industrial Minerals Div., Rocky Mountain Region; Roger V. Pierce, Chairman, Utah Section; J. M. Ehrhorn, Vice Chairman, Utah Section; R. E. O'Brien, AIME Field Secretary; C. R. Fish, Secretary-Treasurer, Utah Section; and Glen Burt, Secretary-Treasurer, Utah Section.

Nominating Committee For AIME Officers, 1956

The following have been named by the Council of Section Delegates, the Branch Councils, and the President of the Institute to constitute the Nominating Committee for AIME Officers in 1956. The Committee will meet during the Annual Meeting of the Institute in Chicago, Feb. 14 to 17, 1955 and select the official slate. If the principal finds it impossible to attend, the alternate will act in his place; otherwise the alternate will not be present at the meeting of the Committee. Names of alternates are in parentheses.

President Reinartz's Appointments: Edward G. Fox, Chairman, Philadelphia & Reading Coal & Iron Co., Philadelphia, Pa. (Frank Ayer, New York, N. Y.); Charles E. Golson, Colorado Fuel & Iron Corp., Denver, Colo. (Wayne Dowdey, Eimco Corp., Birmingham, Ala.); Richard M. Foose, Franklin & Marshall College, Lancaster, Pa. (Theron W. Reed, Owens-Corning Fiberglas Corp., Newark, Ohio).

Mining Branch Council: H. M. Bannerman, U. S. Geological Survey, Washington, D. C. (E. P. Pfleider, University of Minnesota, Minneapolis, Minn.); E. H. Crabtree, U. S. Atomic Energy Commission, Grand Junction, Colo. (Ian Campbell, California Institute of Technology, Pasadena, Calif.).

Metals Branch Council: Robert F. Mehl, Carnegie Institute of Technology, Pittsburgh, Pa. (H. H. Kellogg, Columbia University, New York, N. Y.).

Petroleum Branch Council: Claude R. Hocott, Humble Oil & Refining Co., Houston, Texas (Paul R. Turnbull, Del Mar Drilling Co., Corpus Christi, Texas).

Council of Section Delegates, Executive Committee: Roger V. Pierce, Salt Lake City, Utah (H. R. Gault, Lehigh University, Bethlehem, Pa.

District 1, New York: James S. Vanick, International Nickel Co., New York, N. Y. (John H. Ffolliott, Miami Copper Co., New York, N.Y.).

District 2, Connecticut: W. E. Milligan, Hammond Metallurgical Laboratory, New Haven, Conn. (Leon W. Thelin, Chase Brass & Copper Co., Waterbury, Conn.).

District 3, St. Louis: Jack H. McWilliams, Aluminum Co. of America, Bauxite, Ark. (Carl H. Cotterill, American Zinc, Lead & Smelting Co., St. Louis, Mo.).

District 4, Pittsburgh: Hugo E. Johnson, Lake Superior Iron Ore Assn., Cleveland, Ohio (John C. Calhoun, Pennsylvania State University, State College, Pa.).

District 5, Chicago; R. A. Lindgren, International Harvester Co., Chicago, Ill. (C. T. Hayden, Sahara Coal Co., Chicago, Ill.).

District 6, Black Hills: James O. Harder, Homestake Mining Co., Lead, S. D. (Max W. Bowen, Golden Cycle Corp., Colorado Springs, Colo.).

District 7, Oregon: D. W. Johnson, Reynolds Metals Co., Troutdale, Ore. (Thomas J. Waters, Carbide & Alloys Co., Portland, Ore.).

District 8, Southern California: Basil Kantzer, Union Oil Co. of California, Los Angeles, Calif. (Ian Campbell, California Institute of Technology, Pasadena, Calif.).

District 9, Carlsbad Potash: George E. Atwood, Duval Sulphur & Potash Co., Carlsbad, N. M. (C. E. Presnell, International Minerals & Chemical Corp., Carlsbad, N. M.).

District 10, Delta: Byron L. Francis, Texas Co., New Orleans, La.

Announce 1955 Honors

Honors to be conferred at the annual banquet, Feb. 16, 1955, in Chicago:

James Douglas Medal to Edwin Letts Oliver; Erskine Ramsay Medal to George Herman Deike, Sr.; Robert W. Hunt Medal to F. W. Boulger and R. H. Frazier; J. E. Johnson, Jr., Award to Gust Bitsianes; Rossiter W. Raymond Award to Harold Vagtborg, Jr.; Mathewson Gold Medal to W. G. Pfann; Robert H. Richards Award to Edward W. Davis; Peele Award to R. E. Thurmond, W. E. Heinrichs, Jr., and E. D. Spaulding; Alfred Noble Prize to C. S. Roberts.

Complete details of awards will appear in the January 1955 issue of MINING ENGINEERING.

AIME–ASME Pittsburgh Fuels Meet Crowded

The 17th Annual Fuels Conference October 28 and 29, of the AIME Coal Div. and the ASME Fuels Div. ran into one complication. The Ninth Annual Off-the-Record Meeting of the Pittsburgh Section, AIME, was held on the 29th and at the same hotel.

However, the Conference reaped an indirect benefit from the clash of meeting dates. The fourth and last technical session attracted about 250.

Two hundred and twenty-two registered for the Fuels Conference and 725 for the Off-the-Record Meeting, a total of 947. The latter meeting was divided into sessions on Friday for the Coal Div., the respective Pittsburgh Sections of the Institute of Metals Div. and Petroleum Branch, and the Pittsburgh Branch of the National Open Hearth Committee. The Friday coal sessions were held jointly with the Fuels Conference.

The technical papers presented at the four Conference sessions are as listed on page 930 of the September MINING ENGINEERING. Those on Friday afternoon were not included. The paper by W. I. Collins on *Small and Medium Size Applications of the Cyclone Furnace*, is ASME paper 54Fu3; *Traveling Grate Application Experience with Strong Caking Coals*, by J. M. MacLachlan, is ASME paper 54Fu-4; *Coking Properties of Pittsburgh District Coals*, by F. W. Smith, D. A. Reynolds, and D. E. Wolfson is in AIME reader routine. It is understood that the informative paper by A. H. Brisse and J. H. Wells, *Selection of Coals for Coking*, is not for publication; *Air Pollution Problems with Heat Drying of Fine Coals*, by C. W. Gordon is ASME 54Fu-1, and H. F. Hebley's exceedingly impressive presentation of *Problems Encountered with Industrial Waste Water*, was off-the-record. The fourth session papers, all off-the-record, were: *The Konnerth Miner*, by R. C. Beerbower, Jr.; *Highwall Mining in Thin Seam with Colmols and Extensible Belt Conveyors*, by M. A. Shoffner; *The Goodman 500 Miner*, by E. H. Shaw; *The —1—CM2 Joy Continuous Miner*, by Stephen Canonico, and *Joy Continuous Miners with Extensible Belt Conveyor—Pittsburgh No. 8 Seam*, by Morgan Williams.

On each of the two days there were a luncheon, a cocktail party, and a banquet or dinner. Affairs on the first day were essentially Fuels Conference; the second luncheon (29th) might possibly be described as an integration of the two groups, and Friday the AIME Fellowship Dinner was attended by 330.

T. C. Wurts presided at the Conference luncheon and with him at the head table were T. E. Purcell, Chairman, Fuels Conferenee General Committee; R. B. Engdahl, Chairman

Left, John F. Barkley, the 1954 recipient of the Percy Nicholls Award, with M. D. Cooper, Chairman of the AIME Coal Div.

Fuels Div. ASME; L. K. Sillcox, President ASME; L. F. Reinartz, President AIME; D. W. VerPlanck, Chairman, Pittsburgh Section ASME, and M. D. Cooper, Chairman, Coal Div. AIME. President Sillcox spoke on the ASME; President Reinartz on the AIME. In introducing Mr. Reinartz, Mr. Wurts noted that the former was in one of the earlier classes of Carnegie Tech at a time when Mr. Wurts' father was professor of electrical engineering at Tech. Mr. Reinartz dwelt on a number of interesting AIME topics. He had spent the morning with President Sillcox being shown possible sites for a new engineering societies building. He presented reasons why a young man should want to join an engineering society—the pride and benefit of being a member of his own professional family, to be informed of the progress in science and industry, and for the contacts with his fellow engineers. He said that to maintain our position in the world we must graduate more engineers—must interest bright high school boys in engineering.

T. E. Purcell presided at the Conference banquet. P. H. McCance was toastmaster, R. L. Ireland, chairman of the executive committee of Pittsburgh Consolidation Coal Co., was the after-dinner speaker, and with them at the head table were Presidents Sillcox and Reinartz, R. B. Engdahl, M. D. Cooper, John F. Barkley, David Morgan, ASME President-elect, and D. W. VerPlanck.

Mr. Ireland touched emphatically on many topics: unreasonable ordnances, smoke abatement, stream pollution, the acid mine water problem (no answer to date; needs more technical research), surface subsidence, strip mining (contour plowing), union contracts, seniority clause, too many little men in the coal industry fighting among themselves, research (coal is way behind oil and gas in research), civic responsibility, and need for intelligent long-range selling (basic function of coal is production of energy; new products won't do the job).

M. D. Cooper presented the Percy Nicholls Award for 1954 to Mr. Barkley, appropriately detailing the latter's achievements. The citation for the award to Mr. Barkley portrays the man:

> As a member of the American Institute of Mining and Metallurgical Engineers and a Fellow of the American Society of Mechanical Engineers, currently chairman of the Coal Utilization Committee of the American Institute of Mining and Metallurgical Engineers, past chairman of the Model Smoke Law Committee of the American Society of Mechanical Engineers, together with his unselfish and painstaking work on many other committees of both societies, he has endeared himself to the Fuels fraternity.
>
> His early and continued interest in fuels, combustion and abatement of air pollution, together with his contributions on related subjects in the form of reports, papers, and informative media, have been of inestimable value to the engineering profession and to the nation.
>
> Under his hand and direction high efficiencies and fuel savings have been realized in plants of the United States Government.
>
> His advice has often been sought and freely given. In him we recognize an engineer of outstanding competence, thoroughness, and foresight.

The Conference was assisted at the technical sessions by student aides whose work was gratefully acknowledged by the chairmen of the respective sessions. They were: Ronald D. Rorabaugh, John R. Gibbon, Raymond W. Sutton and Robert Fox of Carnegie Institute of Technology; Paul D. Floyd, Howard E. Megahan, Calvin C. Patterson and George E. Saxon, University of Pittsburgh.

The 18th Annual Fuels Conference will be held at the Neil House, Columbus, Ohio, Oct. 19 and 20, 1955 (Wednesday and Thursday). Elmer Kaiser will be Chairman of the 1955 Conference Committee, with William T. Reid as Co-chairman. Other members of the 1955 committee are A. B. Clymer, publicity; J. R. Garvey, plant trips; G. E. Haney, printing and signs; W. C. Holton, technical, C. J. Lyons, registration; J. H. Melvin, finance; J. M. Pilcher, entertainment; M. L. Smith, hotel.

Program chairmen, hard-pressed for a lively, though instructive afterdinner feature, may well note the talk by R. G. Fithian on the transistor.—E.J.K.Jr.

1955 Publications Policies Established

Pursuant to Article X of the bylaws of the AIME, the following information is hereby given as to the "conditions, prices, and terms under which the various classes of members, and Student Associates, severally, shall be privileged to obtain publications of the Institute during the ensuing year."

Publications authorized for issue in 1955 include the following: MINING ENGINEERING, published monthly, containing material, including technical papers, of interest to those engaged in exploration, mining geology and geophysics; metal, nonmetallic, and coal mining and beneficiation; and fuel technology. The JOURNAL OF METALS, published monthly, containing material, including technical papers, of interest to those engaged in nonferrous smelting and refining, iron and steel production, and physical metallurgy. The JOURNAL OF PETROLEUM TECHNOLOGY, published monthly in Dallas, containing material, including technical papers, of interest to those engaged in petroleum and natural gas drilling and production.

Annual subscriptions to any one of the above journals will be provided all members in good standing without further charge, a subscription credit of $6 for members and $4 for Student Associates being included in the dues paid. (A member ceases to be in good standing if current dues are not paid by April 1). If more than one of the monthly journals is requested, $4 extra will be charged for an annual subscription, or 75¢ for single copies of regular issues and $1.50 for special issues. The nonmember subscription price for each journal is $8 in the Americas and U. S. possessions; foreign, $10, and for single issues 75¢ in the Americas and $1.00 foreign for regular issues and $1.50 for special issues. Student Associates will be entitled to the same privileges for all publications as members. AIME members subscribing to more than one of each of the three monthly journals will be billed at the nonmember rate of $8 per year, domestic; $10 foreign, for the extra subscription(s).

Three volumes of *"Transactions"* are authorized for 1955 publication, as follows: No. 199, Mining Branch; No. 200, Metals Branch; and No. 201, Petroleum Branch. Volumes 199 and 201 will be available to members at $3.50 each for a first copy if paid for in advance with dues; otherwise at the nonmember rate of $7 less 30 pct. Nonmembers $7 in the United States; foreign $7.50. Volume 200 will be available to members at $4.50 each for a first copy if paid for in advance with dues; otherwise at the nonmember rate of $9 less 30 pct. Nonmembers $9 in the United States, foreign $9.75.

Special volumes now planned for publication in 1955 include the following: *Open Hearth Proceedings*, Vol. 38, price to AIME members $7; nonmembers, $10. *Blast Furnace, Coke Oven, and Raw Materials Proceedings*, Vol. 14, AIME members $7; nonmembers $10. *Electric Furnace Steel Proceedings*, Vol. 12, AIME members $7; nonmembers $10. *Statistics of Oil and Gas Development and Production*, Vol. 8, covering data for the year 1953, members $5, nonmembers $10. AIME *Directory and Yearbook*, or equivalent free to members.

If dues are paid subsequent to January 31, back issues of Institute publications will be supplied only if adequate stocks are on hand. A member is not entitled to receive a volume of *"Transactions"*, or a special volume, in lieu of a monthly journal, free of charge on membership. Members in arrears for dues are not entitled to special members' prices for publications.

Rocky Mountain Members may have their choice of an annual subscription to one of the monthly journals on request.

Dues Bills In Mail

Pursuant to Article II, Section 2, of the bylaws of the AIME, notice is hereby given that dues for the year 1955 are payable Jan. 1, 1955, as follows: Members and Associate Members, $20; Junior Members for the first six years of Junior Membership, $12, and thereafter, $17; Student Associates (including an annual subscription to a monthly journal), $4.50.

Dues bills were mailed during the latter part of November. Prompt payment will assure uninterrupted receipt of the publications desired in 1955. If, for any reason, a bill is not received within a reasonable time, headquarters should be notified.

Institute Names 1955 Legion of Honor

Each year at the Annual Banquet in February, those members of the AIME who have continuously maintained their membership for 50 years are given special recognition. They are seated at the head table as guests of the Institute and are added to the membership of the Legion of Honor. The names of those who will achieve this status in 1955 are as follows:

Agaberg, Edgar C.
Bengal, India
Austin, Albert M.
New York, N. Y.
Blomfield, A. L.
Kirkland Lake, Ont., Canada
Carpenter, Arthur Howe
Chicago, Ill.
Cowans, Frederick
Pasadena, Calif.
Dilworth, John B.
Upper Darby, Pa.
Fink, William N.
Chihuahua, Mexico
Foote, Arthur B.
Grass Valley, Calif.
Fox, Alfred, Jr.
Birkenhead, England
Garrey, George H.
Denver, Colo.
Hamilton S. Harbert
Philadelphia, Pa.
Hammer, William L.
Corpus Christi, Texas
Harris, Henry
Worthing, Sussex, England
Hawxhurst, Robert, Jr.
San Francisco, Calif.
Kelley, Cornelius F.
New York, N. Y.
Krumb, Henry
New York, N. Y.
Rakowsky, Victor
Joplin, Mo.
Speller, F. N.
Pittsburgh, Pa.
Vail, Richard H.
Panajachel, Guatemala
Vallat, Benjamin W.
Pacific Palisades, Calif.
Wang, C. Y.
New York, N. Y.
Williams, R. Y.
Pottsville, Pa.
Wright, Charles Will
Washington, D. C.
Wyer, Samuel S.
Columbus, Ohio

Membership Emblem Proposed by Institute

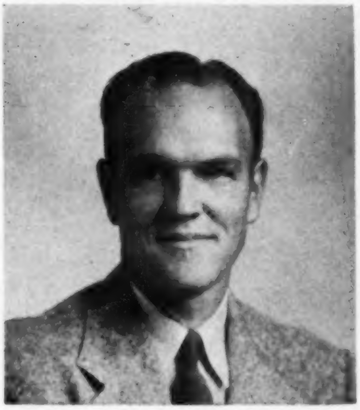
On November 1, a newly designed emblem was instituted by the AIME Membership Steering Committee. This button was pro-

posed as a tangible recognition to individual members who are successful in securing five membership applications for the grades of Member, Associate or Junior Member.

Applications now carry a credit line on which the Member responsible for getting the application should insert his name. The Institute Activities Dept. will keep score and make the presentation on a suitable occasion.

The first button recognizes ability to gather in five applications. Further recognition for 10, 15, 20, and up, in multiples of five await those energetic enough to do the superlative.

Personals



ALBERT A. LEWIS

Albert A. Lewis, who for the past nine years has been employed by the Aluminum Co. of America in the Mining Div. as a field engineer and mining geologist, resigned in July. Mr. Lewis has undertaken consulting work in offices with E. A. Messer & Associates in Portland and Hillsboro, Ore.

Erich Sarapuu, former director of research, Sinclair Coal Co., Kansas City, has announced the formation of Electrotherm Research Corp. This new Kansas City company specializes in the electrotherm process of oil recovery from depleted fields and the underground electrocarbonization of coal. Mr. Sarapuu, president of the new firm, is discoverer of the electrotherm process.

J. M. Currie, formerly with Sunshine Lardeau Mines Ltd., Beaton, B. C., is now with Williamson Diamonds Ltd., Shinyanga District, Tanganyika Territory, East Africa.

Felix J. Losson, Jr., has been appointed to the post of manager of the Mining Div., Lakeland Engineering Associates, Lakeland, Florida. Mr. Losson, formerly chief engineer of the Florida Phosphate Div., Davison Chemical Co., Bartow, Fla., received his B.S. and M.S. in metallurgical engineering from Purdue University in 1942 and 1947, respectively.

Raymond Garcia-Loera has resigned his post as assistant superintendent of production, Cananea Consolidated Copper Co. S.A., Cananea, Sonora, Mexico, to accept the position of research engineer with the Parral unit of American Smelting & Refining Co., Chihuahua, Mexico.

David E. Green has opened the Coachella Engineering Laboratory, 51-557 Highway 99, Coachella, Calif. The laboratory will serve the water supply, agriculture, and mining industries in analyses, treatment and processing, and geology. Mr. Green was formerly a research engineer for Filtrol Corp., Vernon, Calif.

Frederic H. Megerth, metallurgical engineer, research dept., Anaconda Reduction Works, Anaconda, Mont., is now with the 549th Engineer Co. (Survey Base), Fort Winfield Scott, Calif.

Alexander J. Speal, mining geologist with Tungsten Mining Corp., Henderson, N.C., is with the Atomic Energy Commission, Hot Springs, S.D.

Norman H. Parker has been appointed manager of engineering for the Turbo-Mixer Div., General American Transportation Corp., New York. Mr. Parker will have responsibility for the chemical engineering aspects of the design of Turbo-Mixer equipment with special emphasis on applications in the field of hydrometallurgy. He will be in charge of engineering sales of this equipment.

W. E. Snow, who was with Cía. Minera de Alarcón S.A. in Taxco, is now with American Smelting & Refining Co., Chihuahua, Chih, Mexico.

C. F. Schaber of Deming, N. M., left N. Y. in October for an examination of properties far up a tributary of the Amazon.

W. Jewitt is with Rix Athabasca Uranium Mines Ltd., Uranium, Sask. He was with Pioneer Gold Mines Ltd., Vancouver, B. C.

D. Abbott is field geologist, Anglo American Corp. Ltd., Johannesburg, Union of South Africa. He was with South West Africa Co. Ltd., Grootfontein, S. W. Africa.

REUEL E. WARRINER

Reuel E. Warriner, who was in charge of sales to the steel industry for International Nickel Co. Inc., New York, is now vice president, sales, Climax Molybdenum Co., New York. Mr. Warriner had been in charge of Inco's steel section of the nickel sales dept. since 1943 and had been associated with Inco for over 19 years.

Robert S. Archer has been appointed chief metallurgist of Climax. Mr. Archer has been with this company for ten years.

R. R. WILLIAMS, Jr.

R. R. Williams, Jr., has been appointed manager of mines for Colorado Fuel & Iron Corp., Pueblo, Colo. Formerly assistant manager of mines, he succeeds **George H. Rupp** who died October 11. (See *Obituaries* page 1225). Mr. Williams has been with CF&I since 1925.

Robert E. Dye, vice president and general manager, Domes Mines Ltd., South Porcupine, Ont., has retired to Gallagher Ranch, San Antonio, where he will devote his time to ranching and to potash mining at Carlsbad, N. M. Mr. Dye was with Domes Mines for 18 years.

James C. Gray has been appointed vice president, coal operations, U. S. Steel Corp., Pittsburgh. Mr. Gray, who was manager of manufacturing operations, U. S. Steel's Tennessee Coal & Iron Div., Birmingham, will head the company's coal mining activities in Pennsylvania, West Virginia, and Kentucky. He succeeds **Karl L. Konnerth.**

Edwin F. Atkinson is now with Homestake gold mine, Lead, S. D.

Commander R. V. Taborelli, USNR, at his request was released to inactive duty on October 31, after 13½ years of continuous active duty with the Navy as an ordnance specialist. His latest duty was with the Bureau of Ordnance in Washington, D. C., as branch head in the Material Div. Commander Taborelli plans to establish his home in Albuquerque, N. M., where his business connection will be with Martin Laboratories.

Milton H. Marshall, mining engineer, is now with the U.S. Bureau of Mines, Raleigh, N. C., where he has been assigned to Southeastern monazite study. Mr. Marshall was assistant staff engineer, Colorado Plateau Exploration, USGS, Grand Junction, Colo.

Edmund McCarthy is now a consulting engineer with Pocahontas Fuel Co. Inc., Salem, Mass. He was with the Pittston Co., New York.

William Justin Kroll of Corvallis, Ore., was awarded a Francis J. Clamer Medal by the Franklin Institute, Philadelphia, October 20, "In consideration of his invention of a method adaptable to the large-scale production of cold malleable commercially pure titanium and zirconium." He has been granted 47 patents both here and abroad. Mr. Kroll, who is also the author of numerous technical papers, was awarded the James Douglas Medal by the AIME in 1953.

T. N. Armstrong, a member of International Nickel Co.'s Development & Research Div. in New York, has been named chairman of the newly formed committee on interpretive reports of the Welding Research Council. These reports will be issued three times a year.

THOR H. KIILSGAARD

Thor H. Kiilsgaard, formerly project chief, Defense Minerals Activities Northwest Region, U. S. Geological Survey, Spokane, is staff assistant, Defense Minerals Exploration Administration, USGS, Washington, D.C.

John H. Jett has joined Vulcan Iron Works Co., Denver, as sales engineer. He was with the Mining Div., AEC, Grand Junction, Colo. He is a graduate of the College of Mines, University of Arizona and was employed for many years by Phelps Dodge Corp. in the production dept. at Bisbee, Ariz.

C. L. Sarff, who was with Hanna Coal Co., Adena, Ohio, is now with White Pine Copper Co., White Pine, Mich.

Leo F. Reinartz, vice president, Armco Steel Corp., Middletown, Ohio, and president of AIME, has been named president of Princess Dorothy Coal Co., Eunice, W. Va., which Armco recently acquired. **Andrew Hogue,** former president, will be vice president in charge of operations.

F. R. Werther, formerly general superintendent, North Range Mining Co., Negaunee, Mich., is now with Pickands, Mather & Co. general mining offices in Duluth.

John J. Curzon, who recently resigned as manager of Chelan Div., Howe Sound Co., Holden, Wash., has been appointed deputy director of the Mining Div., AEC, Grand Junction, Colo. Mr. Curzon joined Howe Sound Co. in 1937 as chief engineer. Prior to that he was superintendent, Eureka Mining & Milling Co., Republic, Wash., superintendent, Coeur d'Alene Mines Corp., Wallace, Idaho, and with mining companies in British Columbia and Alaska. Mr. Curzon was also with the City Engineering Dept. in Seattle.

Jordan H. Rockefeller and **Ralph Edfort** have joined Wilmot's engineering dept. at the White Haven, Pa., plant. Mr. Rockefeller, a graduate of Rensselaer Polytechnic Institute, has been with Lehigh Valley Coal Co. since 1920 and assistant mechanical engineer there since 1935. Prior to that he was with Carnegie Steel Co. Mr. Edfort came from Landis Machine Co., where he served as designing engineer. **Otto von Perbandt,** who recently joined Wilmot Engineering Co. as contracting engineer for the Coal Preparation Div., has assumed a similar responsibility for sales of the new Ore Concentrator Equipment Div. **Henry Otto** has been placed in charge of sales for both equipment divisions in the western Pennsylvania and eastern Ohio territories. He formerly represented the company in the northern Pennsylvania anthracite area. **Gene F. Scarborough** has been named representative in the Atlanta territory for Wilmot's Keystone Rivetless Chain Div.

Frederick B. Brien is assistant professor, ore dressing dept., University of Washington, Seattle. He was ore testing engineer, Hudson Bay Mining & Smelting Co., Flin Flon, Manitoba.

DAVID C. SHARPSTONE

David C. Sharpstone, consulting geologist to the Ventures Group and chairman and managing director of Kilembe Mines Ltd., has been appointed a director of Uganda Development Corp. through an order on council by Sir Andrew Cohen, Governor of Uganda.

H. GORDON POOLE

H. Gordon Poole has been appointed head of the dept. of metallurgy, Colorado School of Mines, Golden. Mr. Poole was an associate professor of extractive metallurgy at Case Institute of Technology, Cleveland, and before that with the mining dept., University of Washington, Seattle. He has worked on mining and metallurgical engineering projects in the U.S., Canada, Mexico, Ecuador, Colombia, and Bolivia, in addition to serving with the U. S. Bureau of Mines in Salt Lake City, Seattle, Albany, Ore., and Washington, D. C. Other appointments at Colorado School of Mines include **Howard L. Hartman,** assistant professor of mining, who was with the University of Minnesota, **Douglas W. Bainbridge** as assistant professor of metallurgy, and **Hildreth Frost, Jr.,** as instructor in metallurgy.

Frank Coolbaugh, vice president, western operations, Climax Molybdenum Co., Climax, Colo., has been elected president and a director of Climax Uranium Co. He replaces **John H. White, Jr.,** who has resigned. Except for service during World War II, Mr. Coolbaugh has been with Climax since shortly after graduation from Colorado School of Mines in 1933.

Roy C. Kepferle, recently a graduate student, South Dakota School of Mines & Technology, Rapid City, is now a geologist, Western Fuels Section, Geologic Div., USGS, Denver.

Lloyd Gibson of Scarsdale, N. Y., is retiring from the tax dept., Standard Oil Co. (N. J.), New York. Mr. Gibson has been with this company since 1934. Following office and field service with the Oil & Gas Section, Income Tax Unit, Washington, D. C., he served as chief of this section. Mr. Gibson graduated from West Virginia University of Engineering in 1917 and after service in the Army Engineers in World War I, spent many years in coal mining and in oil and gas geology.

Ernest M. Spokes is now associate professor of mining engineering, University of Kentucky, Lexington.

B. E. GRANT

B. E. Grant has resigned his position as director of labor relations, U.S. Smelting Refining & Mining Co., Salt Lake City. Mr. Grant plans to establish a management service and consulting office in Salt Lake City, directing particular attention to uranium mining and production. He is a graduate in mining geology from the University of Utah and did post-graduate work at Utah, at the University of Idaho, and at the University of California at Berkeley.

John Franklin Lane is with Lisbon Uranium Corp., Moab, Utah.

P. T. Flawn has taken a leave of absence for three months from the Bureau of Economic Geology, University of Texas, Austin, as consulting geologist with the Surface Geological Co., Albuquerque.

William F. Haddon, for the past three years advertising manager for General Metals Corp., has been made advertising manager, Western Machinery Co., San Francisco. Mr. Haddon was with Denver Eqpt. Co. for several years and began his connection with this firm as editor of *Deco Trefoil.*

Ralph J. Holmes, a member of World Mining Consultants Inc., New York, recently headed a mission that completed a comprehensive mineral resource survey of Somalia for the Italian Government. **Gabor Dessau** of Rome was also a member of this group. A program of exploration of tin, iron ore, ilmenite, and barite deposits was recommended.

Dooley P. Wheeler, Jr., resigned in October as superintendent, Western Exploration, The American Metal Co. Ltd. and has opened a geological consulting office at 912 Kearns Bldg., Salt Lake City.

Walter J. Akert has been named concentrator superintendent, Nevada Mines Div., Kennecott Copper Corp., McGill, Nev. He replaces **L. G. Immonen** who resigned to accept a position with a Henderson, Nev., chemicals manufacturing firm.

Wayne Barney, for the past two years a graduate student at the University of Arizona, Tucson, is now a metallurgical engineer with General Electric Atomic Products Group. Mr. Barney is on a rotating assignment program for chemists and metallurgists and was recently with Aircraft Gas Turbines Div. for three months and with aircraft nuclear propulsion dept. for three months.

Donald H. McLaughlin, president of Homestake Mining Co., San Francisco, has been named a director of Western Air Lines Inc.

Philip W. Chase, director, exploration and development with U.S. Steel in Pittsburgh, has been appointed assistant vice president, Raw Materials, U. S. Steel Corp. He succeeds **H. D. Moulton** who was recently elected president of U. S. Steel Homes. **August J. Breitenstein,** director of planning, Raw Materials Div., has been appointed director of exploration and planning. Mr. Chase was first employed by U. S. Steel in 1946 and 1947 while he was a consulting geologist. He became a full-time employee in 1948 when he joined the Oliver Iron Mining Div. as manager, special investigations and explorations. Mr. Breitenstein joined the company as a mining engineer with the H. C. Frick Coke Co. in 1941.

G. G. HATCH

G. G. Hatch, director of research, Quebec Iron & Titanium Corp. since 1952, has been appointed plant superintendent of the company's operations at Sorel, Que. Succeeding him as research director is **P. J. Ensio,** research metallurgist with Quebec Iron & Titanium since 1953. Mr. Hatch was formerly research metallurgist with Shawinigan Water & Power Co., Shawinigan Falls, Que., and with Armour Research Foundation, Chicago. Mr. Ensio has been employed as a research metallurgist by International Nickel Co. of Canada Ltd., Copper Cliffs, Ont., and as a consulting metallurgist for Mount Royal Metal Co., Montreal.

Obituaries

C. Jackson Abrams

An Appreciation by

Frank Coolbaugh

Jack Abrams (Member 1936) died at his home in Denver on Oct. 17, 1954.

Mr. Abrams was born in the Mother Lode area of California at Biggs on Jan. 16, 1890. After finishing high school, he established his interest in mining by working in the mines and placers around Oroville. In 1912, he entered the University of California where he graduated with a degree in mining engineering in 1916. After finishing college he worked for a short time with the California State Geological Survey. Following this, he worked about a year in the mines around Goldfield and Virginia City, Nev.

In 1917, Jack Abrams married Laura Ricketts whom he had known since entering the university. That same year they moved to Superior, Ariz., where, starting as a laborer, he advanced to foreman at two mining operations and at the mill of the Magma Copper Co. during a period of about three years. Following this, he moved to Sidney Inlet on the west coast of Vancouver Island as manager of a newly developed copper mine. This property was further developed and expanded under Mr. Abrams' direction for the next three years.

In the middle 1920's, he accepted the position of manager of the Hewer mine at Lake View, Idaho, where he remained for four years.

In 1928, Jack Abrams became associated with the Climax Molybdenum Co. at Climax, Colo., as assistant general superintendent of operations under William J. Coulter with whom he had worked at the Vancouver Island property. For the first two years at Climax, his main attention was given to the mining and mine development problems. After that, until 1936, his major efforts were directed to milling and to the expansion of surface facilities in order to keep pace with the growing demand for molybdenum. In the period from 1936 to 1939, he left Climax to become associated with the Colorado Iron Works in Denver in its technical development and sales departments. He returned to Climax in 1939 in the position of general superintendent.

During the period from 1939 to 1951, under his outstanding leadership and technical abilities, the operation at Climax grew from a capacity output of 10,000 tpd to one of more than 18,000 tpd. The known ore reserves were tremendously enlarged. Processes were developed for the recovery of byproduct metals such as tungsten and tin. A modern, well-planned community was built. Labor relations and public relations were vastly improved; an excellent safety program was set up. Recreational and social activity facilities were constructed and maintained to provide a very wide range of participation. Also, research programs were established for the continued improvement of mining and metallurgical methods.

In 1951, he was made general manager of Western Operations and made his headquarters in Denver. Late in 1953, he was appointed to the position of director of exploration and started to organize this new division of the Climax Co. He continued to live and make his headquarters in Denver.

Jack Abrams had a host of friends living throughout the U. S. He had a wealth of wit and humor and an ability to fit his remarks and stories to the proper occasion. An extremely generous person, he continuously contributed to many worth-while charitable programs and gave his time unsparingly to help young men develop a sound interest in life and the future. As a business leader, he had a keen perception and a native ability to make quick and accurate decisions.

He belonged to many clubs and societies and was always happy to carry an extra load of the responsibilities which are necessary to keep such organizations active. Outside of his work and his social activities, he greatly enjoyed an opportunity to fish, hunt, and play golf. He was a great follower of all the major sports and at one time or another had actively participated in most of them.

He is survived by his two sons, C. Jackson, Jr., and J. Robert, two brothers, one sister, and four grandchildren.

An Appreciation of

Charles Augustus Carlow

By Eugene McAuliffe

There passed away at his home, Kincaple, St. Andrews, Scotland, on the morning of Friday, 13th August, one of the great leaders of the British coal mining industry, Mr. Charles Augustus Carlow, the former chairman and managing director of the Fife Coal Co., Ltd., the company's mines located in Fifeshire, Scotland.

Mr. Carlow came of a family connected with the Scottish coal industry for more than a century. His first position was that of a mining engineer student in the Leven office. Quickly adapting himself to the work, he was made medalist Cowdenbeath Mining School during the years 1897 to 1898 and again in 1898 to 1899. He was also medalist in Cowdenbeath Mining School in 1899. On the fiftieth anniversary of the company, he gave his home, Linwood Hall, Leven, as a convalescent home for miners' wives and the company's women workers. Throughout his entire career, he gave much of his time and means to the welfare of his employees, their families and the public. Dr. Carlow never married.

Many honors came to Dr. Carlow, including the presidency of the Mining Institute of Scotland, 1932-36; president of the Institution of Mining Engineers, 1936-38; and in 1946 he was made an Honorary Member of the AIME and a similar honor was conferred on him by the British Institution of Mining Engineers in 1952. The last major honor received by him in 1952, was that of an Honorary L.L.D. by St. Andrews University, the oldest university in Scotland, which dates back to the year 1411.

Mr. Carlow wrote many technical papers relating to coal mining and management, perhaps his *magnum opus* was his paper "World Coal Resources," read at the Seventy-fifth Anniversary meeting of the AIME in March 1947, this paper covering fifty pages in the Anniversary Volume. At this meeting, held in New York City, Dr. Carlow, a man of commanding presence, of affable and courteous demeanor, made many, many friends within the ranks of the Institute.

With thousands here and abroad, it was a great privilege to call Dr. Carlow "my friend."

Necrology

Date Elected	Name	Date of Death
1936	Charles J. Abrams	Oct. 17, 1954
1954	Roy M. Atwater	Oct. 6, 1954
1948	Isaac G. Brown	Aug. 24, 1954
1903	H. H. Claudet	Aug. 8, 1954
1947	Jackson Coffin	Sept. 21, 1954
1936	Arthur L. Harris	Oct. 2, 1954
1941	John Mills Hoff	July 22, 1954
1918	Robert Job	June 1951
1944	Frederick John Kasper	Oct. 19, 1954
1935	F. S. McNicholas	Sept. 1954
1938	William S. Pugh	Jan. 19, 1954
1927	George Herbert Rupp	Oct. 11, 1954
1935	S. Joseph Swainson	Oct. 22, 1954
1950	William T. Turrall	Sept. 22, 1954
1919	Walter F. Rittman	Sept. 26, 1954
1948	M. B. Willey	Unknown

Jackson Coffin (Member 1947) died Sept. 21, 1954 in San Francisco of a heart condition. He was chief engineer, Cananea Consolidated Copper Co., Cananea, Sonora, Mexico. Mr. Coffin was born in Haverhill, Mass., in 1901. From 1922 till 1924 he was employed as a rodman and instrument man for Colorado Fuel & Iron Co., Walsen, Colo. He then worked for Adams Cattle Co., Vermejo Park, N. M., as an instrumentman, estimator, and draftsman on irrigation and coal mine surveys. Mr. Coffin was for many years employed as a statistical engineer with the mining engineering dept., Inspiration Consolidated Copper Co., Inspiration, Ariz. He was later employed by various companies as a development engineer, mine shift foreman, and division mine foreman. Mr. Coffin went with Cananea in 1946 as a caving expert.

Arthur L. Harris (Member 1936) of Dillsboro, N. C., died on Oct. 2, 1954. He and his wife were crossing a street in Monroe, La., when they were struck by an automobile. Mrs. Harris did not die until several days later. Mr. Harris was vice president, Harris Clay Co., Dillsboro, N. C. He

was born in 1886 in St. Louis and received his E.M. from the University of Texas School of mines in 1909. He first worked as an engineer for the Mexican Lead Co. in Monterrey and then for the Cia. Carbonifera Agujita y Anexas, Agujita, Coahuila, Mexico. He was later with Alberts & Harris, Santiago, Dominican Republic, and with the Harris Construction Co., Newton, N. C. Mr. Harris was at various times, president of La Joya Gravel Co., San Benito, Tex., manager of Cia. Minera de Navegantes, Parral, and manager, Cia. Minera de San Bernardino, Juarez, Mexico. He was a consulting engineer for many companies and served the Government as chief engineer, Mica Program, U. S. Purchasing Commission in Brazil and was with the Foreign Economic Administration in Johannesburg, Union of South Africa.

John Mills Hoff (Member 1941) died July 22, 1954. He was president and managing director of Willow Valley Mines Inc., San Francisco, and had retired only a few months before his death. Mr. Hoff was born in San Diego, Calif., in 1892 and studied at St. Mary's College. He gained his early experience doing geological surveying in Monterey County with his father. Mr. Hoff was later employed by Associated Oil Co., Fellow, Calif., and Jansey Drilling Co., Calgary, Canada. As owner of the Murchie mine in Nevada City, Calif., he built the first flotation plant there. Mr. Hoff was general manager of Nevada Custom Milling Co. and general manager of Kate Hardy mine in California. At various other times he was with Nevada City Gold Mines, Inter-Mountain Gold Mines, Valley Gold Mines, Gracy Gold Mines, and Mountaineer Gold Mines.

Appreciation of

George H. Rupp

By Charles E. Golson

George H. Rupp (Member 1927) died Oct 11, 1954 in Pueblo, Colo., after a lingering illness. He was manager of mines of the Colorado Fuel & Iron Corp.

George was born on Nov. 10, 1889 in Bessemer, Mich., and even before college days worked in the Colby, Ironton, and Yale iron mines in Bessemer. Graduating as valedictorian from high school, he first attended the University of Michigan with the idea of becoming a doctor. After a year of pre-med, upon his father's death, he transferred to the Michigan College of Mines. He graduated at the top of a class, in 1913, which has produced quite a number of prominent men, and with his degrees of B.S. and E.M. became engineer for the Gogebic County Road Commission. For two years he was efficiency engineer for the Newport Mining Co. at Ironwood, Mich. Later, he and L. C. Brewer, as partners, operated an independent ore exploration company. This company reopened the old Norrie mine with Rupp as superintendent. This was still in operation as late as 1936 under the new name of the Townsite mine. At this time Rupp also investigated a new discovery of iron ore in the Belcher Islands of Hudson Bay and spent a year in the Far North country living among the Indians and Eskimos.

In 1922, Rupp was employed by the Ford Motor Co. and became superintendent of the Imperial mine at Michigamme, Mich. In 1927, he became associated with Calumet & Hecla Mining Corp. at Calumet, Mich., in charge of mining operations, which employment lasted until 1929.

In 1929, George Rupp joined Colorado Fuel & Iron Corp. as general superintendent of iron mines and quarries. In 1930, the mining department, to include all raw materials produced by C.F.&I., was formed and to his death, George was manager of this department.

George also held two patents, together with an associate, on coal washing and dewatering machines.

George had married Miss Zita Johnson, whom he had beaten out of the honor of valedictorian at high school commencement by 0.2 pct in grades. Besides his widow, he is survived by two daughters and two sons.

George, with his varied career and wide experience, was an outstanding engineer and administrator. He was extremely friendly to youth, and cooperative to all those who met him professionally or in private life; his wit and humor livened the stories of his experience. He was extremely interested in AIME and did everything in his power to interest young engineers in joining the Institute. He leaves a wide circle of friends and associates who will deeply regret his death.

William T. Turrall (Member 1950) died Sept. 22, 1954 of a heart attack. He was a metallurgist with National Lead Co., Westfield, N. J. Until several months ago when mining operations were suspended in the Panther Valley area, he was director of research for Lehigh Navigation Coal Co. and had been with Lehigh since 1949. Mr. Turrall was born in Toronto in 1912. When he was 19 years old he worked as a mill operator for McIntyre Porcupine Mines Ltd. and continued working summers for this Canadian firm while he attended the University of Toronto. Mr. Turrall received his B.A. in 1936 and his M.S. in mining in 1937 and remained at the university as a lecturer in ore dressing until 1941 when he went with the Canadian Bureau of Mines in Ottawa. He was in charge of Industrial Mineral Beneficiation for four years and assistant in charge of Metallic & Industrial Beneficiation for two years. From 1947 to 1949 he was assistant professor in mineral dressing at MIT. Among other organizations, Mr. Turrall was a member of the Canadian Institute of Mining and Metallurgy.

Proposed for Membership

MINING BRANCH, AIME

Total AIME membership on Oct. 31, 1954 was 21,569; in addition 1782 Student Associates were enrolled.

ADMISSIONS COMMITTEE

O. B. J. Fraser, Chairman; R. B. Caples, Vice-Chairman; F. A. Ayer, A. C. Brinker, R. H. Dickson, Max Gensamer, Ivan A. Given, Fred W. Hanson, T. D. Jones, Sidney Rolle, J. H. Scaff, John T. Sherman, F. T. Sisco, Frank T. Weems, R. L. Ziegfeld.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

Alabama
Birmingham—Cowin, Peter G. (A)
Mountain Brook—Van Houten, Charles N., III (M)

Arizona
Tiger—Acton, Leslie C. (R. C/S—S-J)
Tiger—Kline, James A. (M)

California
Bishop—Marsten, Richard O. (R. C/S—J-M)
Chico—Scott, Carroll T. (M)
Claremont—Foster, Richard K. (R. C/S—S-J)
Grass Valley—Tucker, Eugene H. (M)
Los Angeles—Bluemle, Theodore R. (M)
Oakland—Heindel, Richard W. (R. C/S—S-M)
Pebble Beach—Osborne, Richard (M)
Redwood City—Taylor, William F. (M)
San Bruno—Makholm, Leonard O. (J)
San Jose—Damon, Nathan C. (M)

Colorado
Denver—Card, David C. (M)
Grand Junction—Conklin, Quentin E. (M)
Grand Junction—Hill, Don R. (R. C/S—S-M)
Grand Junction—Mull, Jay B. (M)
Grand Junction—Ritter, Gilman C. (M) (R. C/S—S-M)
Grand Junction—Setter, Anton G. (R. C/S—S-M)

Florida
Bartow—Hedrick, Harold N. (M)
Tampa—Drew, George D. (A)

Illinois
Hinsdale—Mann, Donald MacG. (A)
Ottawa—Edwards, Paul K. (R. J)

Indiana
Michigan City—Connelly, Thomas (A)

Kansas
Eudora—Selwald, Donald J. (J)

Kentucky
Louisville—Hanks, Richard A. (J)

Minnesota
Cold Spring—Alexander, John C. (M)
Deerwood—Chilton, Dan R. (R. C/S—S-J)
Minneapolis—Aiken, George E. (R. C/S—S-M)

Montana
Nye—Bley, John (R. C/S—S-M)

Nevada
Eureka—Paroni, Walter A. (C/S—J-M)

New Hampshire
Penacook—Pitts, Parker D. (C/S—A-M)

New Mexico
Socorro—Schilling, John H. (J)

New York
Flushing—Childs, Kenneth P. (J)
New York—Schuetz, Gerhart W. (A)
Tahawus—Jones, Frank R. (M)

North Carolina
Raleigh—Dahl, Doring C. (J)

Ohio
Columbus—Garvey, James R. (R. M)
Columbus—Tucker, Leroy M. (M)

Pennsylvania
Bethlehem—Beggs, Franklyn L. (M)
Kingston—Becker, Norman F. (M)
Lansford—DeLauretis, Anthony J. (J)
York—Frey, William S. (M)

South Carolina
Spartanburg—Skardon, Ambrose H. (M)

South Dakota
Rapid City—Partlo, F. L. (M)

Texas
El Paso—Fugate, William L. (M)
El Paso—Thompson, Jack T. (J)
El Paso—Viescas, Albert H. (M)
Longview—Thomas, Byron K. (M)

Utah
Dragerton—Bowen, Ray J. (R. M)
Salt Lake City—Hansen, Robert M. (M)
Salt Lake City—Horton, Jack O. (M)
Salt Lake City—Seklemian, Robert (M)
Salt Lake City—Story, William M. (M)
Salt Lake City—Tallon, John F. (M)

Washington
Spokane—Alter, Melvin L. (A)

West Virginia
Lorado—Milan, Marcus L. (M)

Alaska
Anchorage—Andersen, Burton L. (M)
College—Cook, Donald J. (C/S—A-M)

Africa
South Africa
St. James Cape—Amdurer, Stanley S. (M)
Southern Rhodesia
Salisbury—Richardson, Clement M. (M)

Australia
Mt. Morgan, Queensland—Westaway, John W., (M)
Northern Territory—Stephens, Desmond C. (C/S—AA-M)

Bolivia
La Paz—Matthieu, Willem (C/S—J-M)
Llallagua, Siglo XX—Grabowsky, Andrevitch I. (J)

Colombia
Cali—Azzaretti, Frank J. (M)
Cali—Lombardo, Louis P. (J)

Malaya
Trengganu—Heywood, Tom T. (M)

Mexico
Mexico City—Ulloa, Salvador (A)
Naica, Chih.—Jauregui, Luis A, (R. C/S—S-M)

Peru
Lima, San Isidro—Trego, Harry E. (A)
Trujillo—Britts, Roman N. (J)

Turkey
Istanbul—Canakcili, Mustafa (A)

— Coming Events —

Dec. 1-3, AIME Electric Furnace Conference, William Penn Hotel, Pittsburgh.

Dec. 3-4, AIME, Columbia Section, joint session with Northwest Mining Assn.

Dec. 10, AIME, Lehigh Valley Section, annual dinner meeting (Ladies' Night), Hotel Bethlehem, Bethlehem, Pa.

Dec. 10, AIME, St. Louis Section, symposium on conveyors, Hotel York, St. Louis.

Dec. 12-15, American Institute of Chemical Engineers, annual meeting, Statler Hotel, New York.

Dec. 26-31, American Assn. for the Advancement of Science, national meeting, University of California, Berkeley, Calif.

Jan. 9-13, 1955, National Sand & Gravel Assn., 39th annual convention, Miami, Fla.

Jan. 12, AIME, Connecticut Local Section, Bridgeport, Conn.

Jan. 13, AIME, Cleveland Section, annual dinner meeting, 6:30 pm, Manger (Allerton) Hotel, Cleveland.

Jan. 17-18, National Agricultural Limestone Institute Inc., 10th annual convention, Hotel Statler, Washington, D. C. Executive committee, January 15; board meeting, January 16.

Jan. 31-Feb. 2, Sixth Annual Southeastern Instrumentation Symposium, University of Florida, Gainesville.

Feb. 3-5, Colorado Mining Assn., annual meeting, Denver

Feb. 10, AIME, Cleveland Local Section, American Room, Manger Hotel, Cleveland.

Feb. 14-17, AIME, Annual Meeting, Conrad Hilton Hotel, Chicago.

Feb. 21-24, American Concrete Institute, 51st annual convention, Hotel Schroeder, Milwaukee.

Mar. 9, AIME, Connecticut Local Section, Bridgeport, Conn.

Mar. 10, AIME, Cleveland Local Section, American Room, Manger Hotel, Cleveland.

Mar. 16, AIME, Connecticut Local Section, annual meeting, Statler Hotel, Hartford, Conn.

Mar. 20-23, American Institute of Chemical Engineers, Kentucky Hotel, Louisville.

Mar. 28-Apr. 1, Ninth Western Metal Exposition, Pan-Pacific Auditorium, and Ninth Western Metal Congress, Ambassador Hotel, Los Angeles.

Apr. 12, Material Handling Institute, spring meeting 10:00 am, Drake Hotel, Chicago.

Apr. 18-19, Third National Air Pollution Symposium, Pasadena, Calif.

Apr. 19-21, Canadian Institute of Mining and Metallurgy, annual meeting, Royal York Hotel, Toronto.

Apr. 28-30, AIME, Pacific Northwest Conference, Spokane.

July 26-July 1, American Society for Testing Materials, annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

Sept. 19-22, AIME, Industrial Minerals Div., fall meeting, Asheville, N. C.

Oct. 6-8, AIME, Utah Section, Rocky Mountain Industrial Minerals Conference, Salt Lake City.

Oct. 6-8, AIME, Minerals Beneficiation Div., fall meeting, Salt Lake City.

Oct. 9-13, American Mining Congress, metal-mining meeting, Las Vegas, Nev.

Oct. 19-20, ASME, AIME, fuels conference, Neil House, Columbus, Ohio.

— Advertisers' Index —

Allis-Chalmers Mfg. Co., General Machinery Div. ..... *
Compton Advertising, Inc.

Allis-Chalmers Mfg. Co., Tractor Div. ..... *
Bert S. Gittins Adv.

American Cyanamid Co. ..... *
James J. McMahon, Inc.

Anaconda Copper Mining Co. ..... *
Kenyon & Eckhardt, Inc.

Aros Electric, Inc. ..... *

Brunner & Lay, Inc. ..... *
Norman P. Hewitt Adv.

Bucyrus-Erie Co. 1143
Bert S. Gittins Adv.

Cape Ann Anchor & Forge Co. ..... *

Caterpillar Tractor Co. 1162
N. W. Ayer & Son, Inc.

Chain Belt Co. ..... *
The Buchen Co.

Cleveland Rock Drill Div. 1136, 1137
Hoffman & York, Inc.

Colorado Fuel & Iron Corp. ..... *
Doyle, Kitchen & McCormick, Inc.

Copco ..... *
J. J. Gibbons, Ltd.

Deister Concentrator Co. 1134
Louis B. Wade, Inc.

DeLong Corp. ..... *
The McCarty Co., Inc.

Denver Equipment Co. ..... *
Bill Bonsib Adv.

Detroit Diesel Engine Div. 1141
Kudner Agency, Inc.

Diamond Products, Inc. ..... *
Ritchie & Sattler, Inc.

Dorr Co., The 1145
Sutherland-Abbott Adv.

Dow Chemical Co., The ..... *
MacManus, John & Adams, Inc.

Dravo Corp. 1139
Ketchum, MacLeod & Grove, Inc.

Dwight-Lloyd, Inc. ..... *
Spooner & Kriegel

Eimco Corp., The 1151
Matsie Co.

Fairchild Aerial Surveys, Inc. 1135
Clyde D. Graham Adv.

Gardner-Denver Co. ..... *
The Buchen Co.

Hardinge Co., Inc. 1134
The W. H. Long Co.

Hercules Powder Co. (Explosives) 1150
Fuller & Smith & Ross, Inc.

Hercules Powder Co. (Flotation) ..... *
Fuller & Smith & Ross, Inc.

Hewitt-Robins, Inc. ..... *
Fuller & Smith & Ross, Inc.

Heyl & Patterson, Inc. ..... *
Dan A. Sullivan Adv.

Ingersoll-Rand Co. ..... *
Rickard & Co.

International Nickel Co., Inc. ..... *
Marschalk & Pratt Co.

Jeffrey Mfg. Co. 1152
Byer and Bowman

Joy Mfg. Co. ..... Third Cover
Walker & Downing

Metal Carbides Corp. ..... *
Meek and Thomas, Inc.

Mine & Smelter Supply Co. 1149
Walter L. Schump, Advertising

Mine Safety Appliances Co. ..... Fourth Cover
Ketchum, MacLeod & Grove, Inc.

Nordberg Mfg. Co. 1154, 1155
Russell T. Gray, Inc.

Northern Blower Co. 1142
Carr Liggett Adv.

Phelps Dodge Refining Co. ..... *
The House of J. Hayden Twiss

Precision Radiation Instruments, Inc. 1225
The McCarty Co.

Sauerman Bros., Inc. 1144
Symonds, MacKenzie & Co.

Sheffield Steel Co. 1140
R. J. Potts-Calkins & Holden Adv.

Sintering Machinery Corp. ..... *
Spooner & Kriegel

Sprague & Henwood, Inc. 1138
Frederick B. Garrahan Adv.

Stearns-Roger Mfg. Co. ..... *
Gray & Co., Inc.

Stephens-Adamson Mfg. Co. ..... *
Glenn, Jordan, Stoetzel Inc.

Stratex Instrument Co. 1134
Frank Bull & Co.

Texas Gulf Sulphur Co. 1146
Sanger-Funnell, Inc.

Traylor Engrg. & Mfg. Co. 1147
The William B. Kamp Co.

Tyler Co., W. S. 1218

United States Rubber Co. ..... *
Fletcher D. Richards, Inc.

Western Machinery Co. 1156
Boland Associates

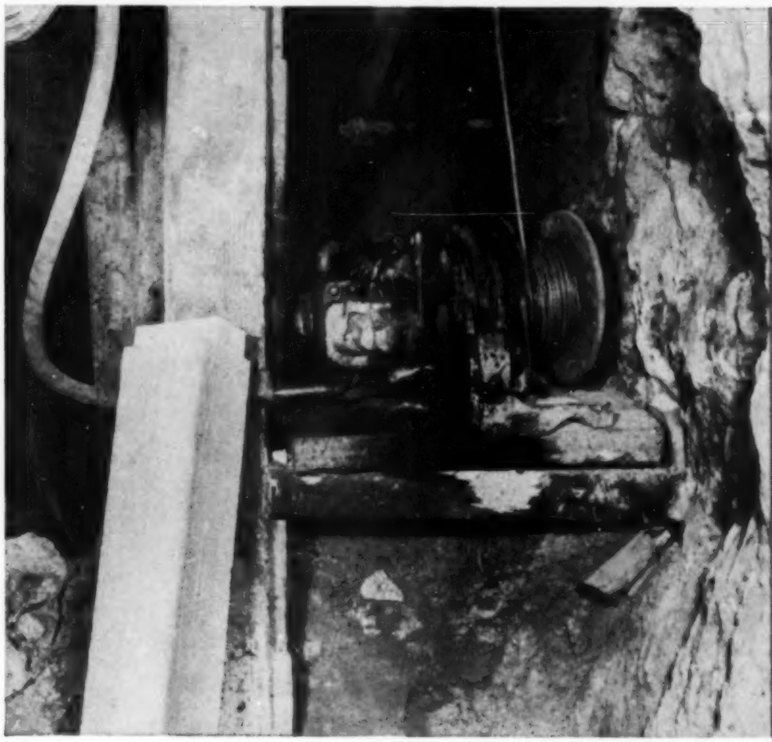
Westinghouse Air Brake Co. 1136, 1137
Hoffman & York, Inc.

Wilfley & Sons, Inc., A. R. ..... Second Cover
Ed M. Hunter & Co.

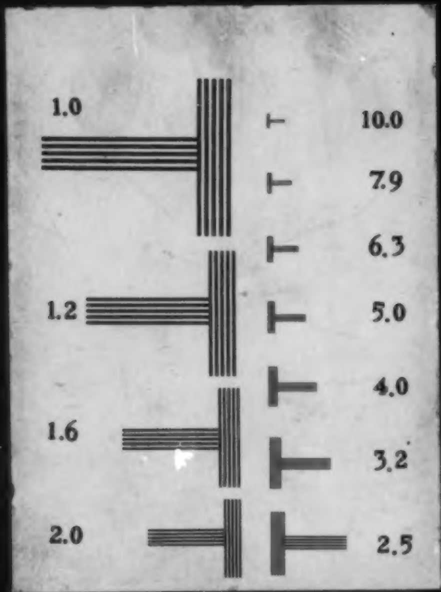
Wilmot Engineering Co. 1223
Wilbur A. Myers Adv.

Yuba Mfg. Co. ..... *
Geo. C. McNutt Adv.

* Previous Issues



RESOLUTION CHART



100 MILLIMETERS

INSTRUCTIONS Resolution is expressed in terms of the lines per millimeter recorded by a particular film under specified conditions. Numerals in chart indicate the number of lines per millimeter in adjacent "T-shaped" groupings.

In microfilming, it is necessary to determine the reduction ratio and multiply the number of lines in the chart by this value to find the number of lines recorded by the film. As an aid in determining the reduction ratio, the line above is 100 millimeters in length. Measuring this line in the film image and dividing the length into 100 gives the reduction ratio. Example: the line is 20 mm. long in the film image, and 100/20 = 5.

Examine "T-shaped" line groupings in the film with microscope, and note the number adjacent to finest lines recorded sharply and distinctly. Multiply this number by the reduction factor to obtain resolving power in lines per millimeter. Example: 7.9 group of lines is clearly recorded while lines in the 10.0 group are not distinctly separated. Reduction ratio is 5, and 7.9 x 5 = 39.5 lines per millimeter recorded satisfactorily. 10.0 x 5 = 50 lines per millimeter which are not recorded satisfactorily. Under the particular conditions, maximum resolution is between 39.5 and 50 lines per millimeter.

Resolution, as measured on the film, is a test of the entire photographic system, including lens, exposure, processing, and other factors. These rarely utilize maximum resolution of the film. Vibrations during exposure, lack of critical focus, and exposures yielding very dense negatives are to be avoided.